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THE JOURNAL OF WILDLIFE MANAGEMENT

VOLUME 25 JULY 1961 NUMBER 3

EFFECTS OF BEAVER ON TROUT IN SAGEHEN CREEK, CALIFORNIA

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During the past several decades there has been a tremendous increase in the number of beavers (*Castor canadensis* Kuhl) in the United States as a result of protection from trapping, and transplantation of breeding stocks. This increase has been accompanied by a growth of interest in the effect that beavers have on other animals, particularly trout. No evaluation of beaver-trout relationships has heretofore been attempted in California and this fact provided the stimulus for the present study.

Sagehen Creek was deemed an appropriate situation for this investigation for several reasons. Since beaver were first introduced into this stream in 1945 (Hensley, 1946) and have been largely undisturbed by man, the effects upon trout of a relatively new and still-expanding beaver population could be determined. Also, since three species of trout, rainbow trout (*Salmo gairdnerii* Richardson), brown trout (*Salmo trutta* L.), and brook trout (*Salvelinus fontinalis* (Mitchill)), are present in Sagehen Creek, any differential effect of beaver on the individual species could be assessed. Finally, this creek is typical of many small streams on the eastern slope of the northern Sierra Nevada.

Arising from two permanent cold (37 to 38°F.) springs at an elevation of 7,400 ft., Sagehen Creek meanders through about 13 mi. of meadow, forest, and sagebrush before emptying into the Little Truckee River at an altitude of 5,800 ft. Melting snows contribute heavily to the stream flow during spring and summer. Minimum fall flows between 1.3 and 2.6 cu. ft. per sec. and maximum spring flows between 38 and 149 cu. ft. per sec. occurred during the years 1954–59 at the Sagehen Creek Project (Fig. 1). Water temperatures over 70°F. in the main stream channel are rare and of short duration. Winter conditions are severe, since the extreme minimum temperatures for the 1954–60 period ranged from –12 to –30°F. and the maximum snow packs ranged from 48 to 131 in. in depth.

When the study began, there were four separate beaver colonies in Sagehen Creek. Since it was not feasible to study all of them in detail, it was decided to study one colony intensively and the others extensively. The so-called "Rockslide Colony" (Figs. 1 and 2) was selected for intensive study because it occupied an area believed to be most representative of average ecological conditions in the stream. Field work was begun in the winter of 1954 and was completed by the summer of 1957.

The beavers of the Rockslide Colony maintained a complex system of 14 dams, and the resulting ponds, together with the dams, could affect trout in a number of ways. In an attempt to determine the effects of beavers and their workings upon trout, a program was set up to study: 1) the physical characteristics of beaver pond and stream areas; 2) the bottom faunas present in pond and stream and the utilization of these organisms by trout; 3) the trout populations present in pond and stream habitats; and 4) the effect beaver dams have on trout spawning migrations.

This study was undertaken while the writer was employed by the University of

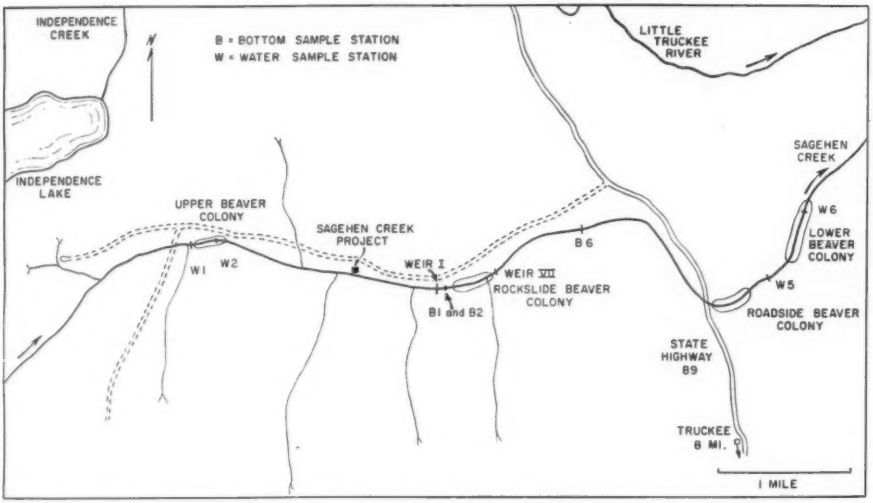

FIG. 1. Reference map of Sagehen Creek and surrounding area.

California, Department of Zoology, at the Sagehen Creek Project. Many of the facilities at the Project were provided by the Max C. Fleischmann Foundation. A. Starker Leopold, Paul R. Needham, and Robert L. Usinger provided valuable guidance and encouragement throughout the study. Aid with various phases of the field work was given by Gerardus C. deRoth, Joseph G. Hall, Robert S. Hoffmann, and by many students who were employed at the Project during the summers. Mrs. Emily Reid prepared the figures. The author is indebted to all these people and grateful for their help.

PHYSICAL CHARACTERISTICS OF BEAVER POND AND STREAM AREAS

General Physical Characteristics

Water velocity was greater in stream than in pond situations. In August the average water velocity at stream stations B1, B2, and B5 was 1.03 ft. per sec. while no measurable velocity occurred in the beaver ponds at B3 and B4 (Figs. 1 and 2). The lack of current in the ponds permitted the deposition of silt on the pond bottoms, where it accumulated to the extent of 1 or 2 ft. in old ponds. Typical stream bottom consisted of rubble, gravel, sand, and occasionally hard-pan, rock, and silt. Differences in water velocities and bottom types were found to influence kinds and standing crops of bottom organisms.

There were some important differences between the vegetations associated with beaver pond and stream areas. Following impoundment of water by beavers, some riparian trees were killed, particularly lodgepole pine (*Pinus contorta* Dougl.). Aspen (*Populus tremuloides* Michx.) occasionally was flooded and killed, but this species in or near a beaver pond was usually cut by beavers for food and for building dams or lodges. Downed aspens formed an interlacing tangle over some ponds and provided ideal trout cover. Bushy willows (*Salix* sp.) grew along parts of the stream and seemed to thrive around the edges of many beaver ponds (Hall, 1960). The aquatic water buttercup (*Ranunculus aquatilis* L.) was more prevalent in ponds than in running waters.

Width and surface area of the stream were increased by ponding. The average width in July at 1,340 randomly chosen stream stations in the upper half of the creek was 11.3 ft.; the average width at 208 stations in the Rockslide and Upper Colonies was 16.6 ft. Beaver Ponds 1 through 13 in the Rockslide Colony (Fig. 2) were found to have a total surface area of 1.273 a. in summer. Following a nearly complete removal of dams by a flood in December 1955, the surface area diminished to 0.873 a., a decrease of 32 percent.

The character of winter ice cover was found to be considerably different in the beaver ponds from that in the faster running waters. During most of the winter, the ponds were continuously capped with several inches of shelf ice overlaid with varying amounts of snow. Anchor ice did not form on

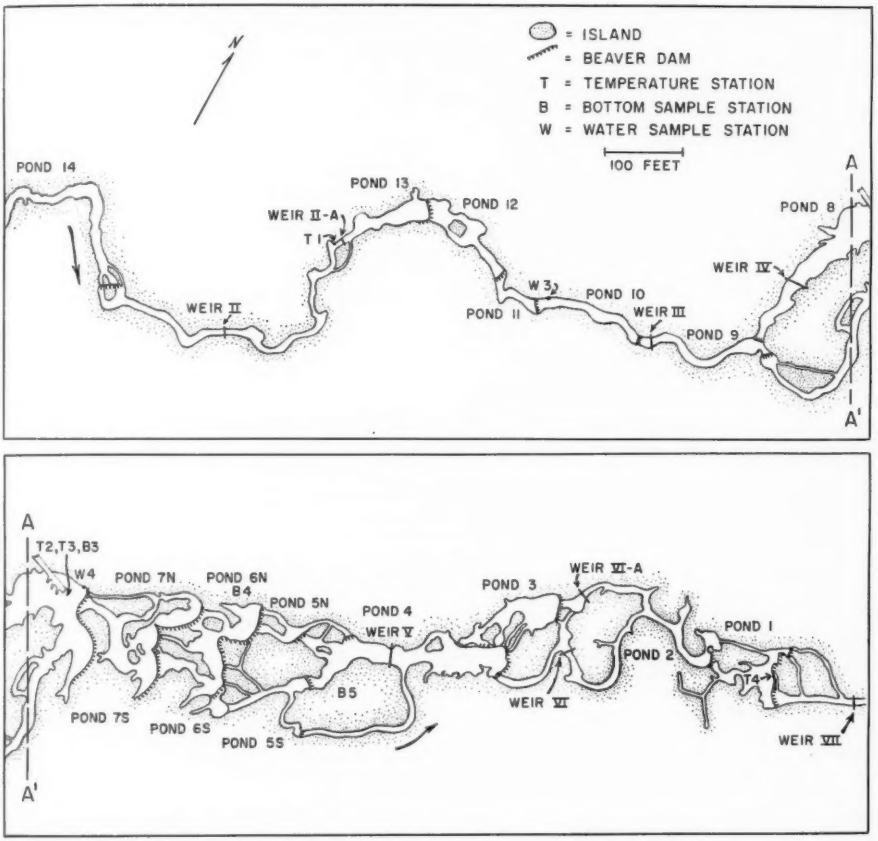

FIG. 2. Map of the Rockslide Beaver Colony on Sagehen Creek.

the pond bottoms. This may have been prevented by the entrance of relatively warm ground water. On the other hand, on cold nights the stream froze almost solid in many riffles where anchor ice built up from the bottom to form dams, and melting and breakup of anchor ice greatly disturbed the stream substrate.

Water Temperatures Above and Below a Pond Series

Monthly averages of late afternoon temperatures of water entering and leaving contiguous ponds in the Rockslide Colony (Stations T1 and T4 in Fig. 2) are shown graphically in Fig. 3. It is evident that water leaving the ponds was colder than that entering at all times of the year except during the spring months, when high flows obliterated any local influences. A small spring with a July temperature of 43°F. entered the Rockslide ponds and doubtless helped cool the water in summer when the flow was low. In midwestern and eastern United States, warming of beaver ponds on summer afternoons has often been reported (Patterson, 1950; Adams, 1953; Reid, 1952). High temperatures may kill trout directly or provide a habitat more suitable for other fish, thus exposing trout to competition with these forms.

In addition to the afternoon temperature series, temperatures of water entering and leaving Rockslide ponds were recorded every 4 hr. for a 24-hr. period once each season. Water leaving the beaver ponds between midnight and noon in summer and fall averaged 3.7°F. warmer than entering water. At other seasons and times, water leaving the ponds was cooled an average of 1.4°F. The ponds

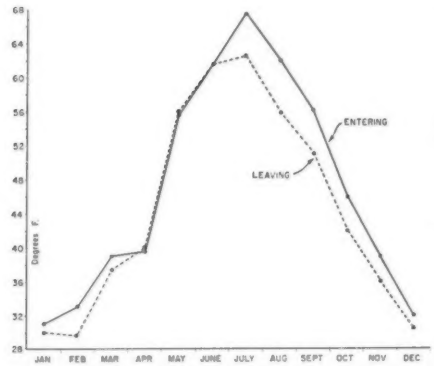

FIG. 3. Monthly averages of afternoon temperatures of water entering and leaving the Rockslide Beaver Colony on Sagehen Creek.

appeared to stabilize water temperatures because pond waters were not influenced as greatly as were stream waters by changes in air temperature.

Temperatures Within One Beaver Pond

The surface and bottom water temperatures at the deepest point in Pond 8 (T2 and T3 in Fig. 2) were recorded periodically on late afternoons for 1 year. Surface temperatures were higher than bottom temperatures during all seasons except winter, when the temperatures at these two stations were about the same (Fig. 4). Afternoon warming of surface waters would have been caused by exposure to warm air and radiant energy. The generally homothermous condition of the pond in winter was maintained by the permanent cover of ice and snow which prevented rapid heat exchange between pond and atmosphere.

In order to check the possibility that temperature stratification was present in Pond 8 in summer, a vertical series of temperatures was taken on a July afternoon. Homothermous water (excluding the very surface) of 67.5°F. extended down to the 24-in. level. Below this upper layer of water, there was a sharp drop in temperature of 4°F. to the 32-in. level followed by a somewhat lesser drop of 2°F. between this level and the bottom at 44 in. Temperatures in the pond were stratified; this may be of importance to trout since the cool lower layer could be used as a retreat during hot days.

Temperature Extremes

The highest water temperature measured, 72.5°F. on August 4, 1955, was at the surface of Pond 8. The lowest temperature, 29°F. on January 25 and 26, 1955, occurred in water flowing out of the Rockslide ponds. This low water temperature may have been the result of supercooling or, more likely, of encasement of the thermometer bulb by ice. Embody (1921) stated that good yields of brook, brown, and rainbow trout occur in New York streams with summer temperatures of 79, 83, and 85°F., respectively. Fry, *et al.* (1946) found the ultimate upper and lower lethal temperatures for brook trout to be 78°F. and below 32°F., respectively. Adams (1953) reported that wild brook trout endured temperatures higher than 80°F. (maximum 83°F.) for a period of 5.5 hr. The highest water temperature (and probably also the lowest) recorded during the present study were within the tolerance ranges of the three trout species.

Water Chemistry

A diurnal series of water samples was taken each season from Pond 8 (W4) and from the stream above (W3) at 4-hr. intervals. Single samples were collected at stream and pond stations in the Upper (W1 and W2) and Lower (W5 and W6) Colonies each season. Dissolved oxygen and methyl orange and phenolphthalein alkalinities in the samples were determined by use of methods outlined in Welch (1948). A *p*H meter was used to assess the degree of acidity.

Water samples from Pond 8 exhibited a yearly range in dissolved oxygen of 7.7 to 11.9 p.p.m., in *p*H of 6.9 to 7.9 units, and in methyl orange alkalinity of 26 to 70 p.p.m. (Table 1). No phenolphthalein alkalinity was found. Almost identical data were obtained from the samples collected at the stream station (W3) above Pond 8. Unlike the condition in the Rockslide Colony, slight decreases in dissolved oxygen (maximum of 1.8 p.p.m.) and *p*H (maximum of 0.6 unit) occurred as the water passed through the Upper and Lower Colonies. Many workers have reported lower dissolved oxygen and *p*H levels in beaver ponds than in the running waters above them (Salyer, 1935; Wilde, *et al.*, 1950; Adams, 1953; Rupp, 1955). The abundant growth of vegetation in the Rockslide ponds may have maintained oxygen and *p*H levels equal to those in the stream above.

FIG. 4. Monthly averages of afternoon temperatures of water at the surface and bottom of Beaver Pond 8 on Sagehen Creek.

TABLE 1.—WATER ANALYSIS OF ROCKSLIDE BEAVER POND 8 IN SAGEHEN CREEK
(Ranges of values over 24-hr. periods)

Date	Water Temperature Degrees F.	Dissolved Oxygen (p.p.m.)	*p*H	Methyl Orange Alkalinity (p.p.m.)	Oxygen Percentage Saturation
April 28, 1954	36.0–49.0	9.1–10.4	6.9–7.4	26–29	96–101
July 30, 1954	51.0–66.0	7.7– 9.8	7.4–7.9	62–67	102–113
Nov. 3, 1954	35.0–42.5	9.8–11.0	7.4–7.8	68–70	98–102
Jan. 25, 1955	32.5–33.5	11.1–11.9	7.5–7.8	63–65	98–104

Though little change in the chemistry of the water occurred as it passed through beaver ponds, elevational and seasonal changes did occur. The water gained an average of 19 p.p.m. in methyl orange alkalinity as it traveled from the Upper to the Lower Colonies. Evidently the longer period of contact of the water with the limestone substrate accounts for this increased alkalinity. The fact that dissolved oxygen was highest in winter and lowest in summer was apparently related to the oxygen-holding capacity of water at different temperatures. Alkalinity was much lower in spring than at any other season and was accompanied by a relatively low *p*H. These changes probably resulted from increased dilution of dissolved bicarbonates by high spring runoff from melting snows.

Trout have long been considered to have high oxygen requirements. Needham (1938) stated that the oxygen content of trout waters should be at least 4 p.p.m. However, trout have been known to live for a limited time under some amazingly low oxygen tensions where temperatures were not excessive. Gutsell (1929) found that some brook trout accustomed to low oxygen tensions survived for a day in water with as low as 1.2 p.p.m. of dissolved oxygen at 59.9°F.; some rainbow trout survived dissolved oxygen tensions as low as 1.6 p.p.m. (66.2 to 68°F.) for a few days. Brook trout in the Bean River, New Hampshire, survived in water temporarily containing only 1.1 p.p.m. of oxygen at 52°F. (Jahoda, 1947).

In the present study, the lowest amount of dissolved oxygen (7.3 p.p.m. at 66°F.) was in a Lower Colony pond in July; the highest (11.9 p.p.m. at 32.5°F.) was in Pond 8 in January. Sagehen waters were always nearly saturated or supersaturated with oxygen.

Trout can live successfully in waters displaying wide ranges in hydrogen-ion concentration. Greene, *et al.* (1933) found brook trout ponds in the upper Hudson River area with *p*H's ranging from 5.4 to 7.1, while Creaser (1930) concluded that the range of voluntary toleration of brook trout to *p*H extended from 4.1 to 9.5. The highest *p*H recorded in Sagehen Creek (7.9) was in the stream above the Lower Colony in July and the lowest (6.9) was in Pond 8 in April.

Since all water quality data determined were well within the lethal limits for trout (where these are known), it is concluded that the slight changes in water chemistry in some of the ponds had no appreciable effect upon trout.

The changes imposed on a stream by damming are those associated with the transposition from a typical lotic to a lentic environment. The physical attributes of ponds appear to offer trout habitat superior to that in streams except for the obvious deficiency of spawning gravels. Greater living space, better cover, slower water velocity, less severe ice conditions, and more stable water temperatures occur in the ponds.

FOODS AND FEEDING OF TROUT IN BEAVER POND AND STREAM AREAS

Samples of the bottom faunas were obtained each season from four stream stations and two Rockslide beaver ponds. Stream-bottom types sampled were gravel (B1), rubble (B2), silt (B6), and rubble between two beaver ponds (B5). Two samples were obtained with a square-foot Surber sampler at each rubble or gravel stream station. At the silt-bottomed stream station, two ¼-sq.-ft. Ekman dredge hauls were taken in summer and spring, one in fall, and none in winter. Pond station B3 was in a comparatively old pond built before 1951, but B4 was in a newer pond built in 1952 or 1953. Four Ekman dredge hauls were obtained from each pond (except in summer when eight were taken), two from shallow areas and two from the deepest points in the ponds.

Surber and Ekman samplers were selected for use since they were the most practical ones available for sampling riffles and ponds, but both fail to catch the entire bottom faunas within their borders. The Surber sampler misses organisms not dislodged from the stream bottom or not washed into the net. Many organisms es-

cape the Ekman since its jaws invariably close on some object that keeps them slightly apart.

A sieve with openings of 0.59 mm. was used to separate the bottom fauna from fine debris. Sieves with openings this large (the one used by most workers in the past) fail to catch many young midges (Jonasson, 1955). Undoubtedly many small organisms were not recovered in the present study. But since these minute organisms weigh so little, it is doubtful that their omission resulted in significantly lower sample weights, although numbers of organisms would be conservatively counted.

The sorted bottom samples were weighed to the nearest 0.01 g. after being pressed against blotting paper for 1 min. Most of the organisms were identified to genus by the use of two references, Usinger (1956) and Pennak (1953); a list of organisms appears in Table 2. Statistical comparisons of averages in this and subsequent sections of this paper were made using the *t* test (Dixon and Massey, 1957, p. 121).

Kinds of Bottom Organisms

The combined stream stations (B1, B2, B5) yielded 81 categories of organisms whereas the combined pond stations (B3, B4) had only 42 for all seasons. That the stream displayed a more diverse assemblage of life than the ponds was to be expected since it presents a relatively heterogeneous environment. A beaver pond, on the other hand, is quite homogeneous and a broad assortment of animal types would not be anticipated there.

Some of the important kinds of organisms found in the ponds were *Sialis* larvae, several genera of chironomid larvae, *Palpomyia* and *Chrysops* larvae, and *Pisidium* and oligochaete adults. Dominant organisms in the stream were *Alloperla, Cinygmula,* and *Ephemerella* nymphs, as well as *Glossosoma* and *Cricotopus* larvae.

Numbers and Weights of Bottom Organisms

Average total numbers and weights of organisms at the beaver pond stations were much greater than those at the stream stations during each season (Fig. 5). When all seasons were averaged together, the ponds contained 1,992 organisms (5.50 g.) and the stream contained 239 organisms (1.03 g.)/sq. ft. (differences significant at the 1 percent level). In New Mexico, Huey and Wolfrum (1956) also found beaver ponds to be much richer in bottom organisms than were stream areas. Contradictory data were obtained in Maine, where beaver pond bottoms contained fewer organisms per unit area than did various stream types (Rupp, 1955).

FIG. 5. Average seasonal numbers and weights of bottom organisms in beaver pond and stream areas of Sagehen Creek. Data from pond stations B3 and B4 and stream stations B1, B2, and B5 are combined.

In accounting for the greater standing crop of organisms in the Sagehen ponds than in the stream, we might first consider temperature differences. The bottom temperature of Pond 8 varied less than did that of the entering stream. Temperature stability in the ponds might have provided more satisfactory conditions for the organisms. Since water chemistry was so similar in pond and stream, it is unlikely that this affected bottom faunas. Perhaps the two most pertinent differences lie in the substrate and current. The basic nutrients contained in the silt of the ponds would be more readily available to plant life because of the much greater surface area of silt particles. Current is slower in the ponds and would not carry away bottom fauna as readily as it would in the stream. Neill (1938), Sprules (1941), and Abell (1956) consider current

the most important factor affecting bottom faunas.

The summer standing crop of bottom organisms in the ponds was significantly lower (1 percent level) than the crops at other seasons (Fig. 5). In the stream, weights were significantly lower (5 percent level) in summer, but numbers were not lower. That fewer organisms were sampled in the ponds in summer was anticipated, since the emergence of adult insects reached its peak then and incoming generations of larvae were too small to be taken by samplers. These data indicate that season must be taken into account when a stream is to be assessed as to its productivity.

Many mollusks lived in the pond bottom, but few of these forms were present in the stream (Table 2). These mollusks were mostly clams (*Pisidium*), but included a few snails (*Physa* and *Gyraulus*). Since much of the weight of these forms is composed of shell and because clams are virtually uneaten by trout in Sagehen Creek, a comparison of pond and stream life was made with mollusks excluded (Fig. 5). Though faunal differences between pond and stream were not as pronounced, the average numbers and weights of organisms in pond samples were still significantly higher (1 percent level) than were those in stream samples.

The comparisons mentioned above are on a unit-area basis. If the standing crop of organisms in the entire Rockslide Colony were compared to that which the same area would support as a stream, an even greater difference would be evident because a ponded stream covers much more area than one without ponds.

No consideration has been given in the foregoing comparisons to relative turnover rates. Allen (1951) estimates that in the Horokiwi Stream the total annual production of the whole bottom fauna must be well over 17 times that of the average standing crop on a numerical basis, or 100 times on a weight basis. These data indicate a very high turnover rate in the bottom fauna. While a thorough treatment of this question is impossible with the data available here, it is known that many genera of midges (the dominant pond organisms) have several generations per year and that most genera of mayflies, stoneflies, and caddisflies (the dominant stream organisms) have only one generation per year. On this basis, the turnover rate of dominant organisms in the ponds would be higher than that for dominant organisms in the stream. The greater richness shown for ponds might therefore be enhanced if turnover rates of bottom faunas were considered.

Comparison of Sampling Stations

Reports have been made that although new ponds are good trout producers for a few years, their yields then gradually decrease (Salyer, 1935; Adams, 1953). Presumably this trend would also be followed by trout foods. At the Rockslide Colony, the new pond possessed somewhat larger numbers and weights of bottom organisms than did the old pond, but the differences were not significant at the 5 percent level.

It has long been known that the character of stream substrate exerts a tremendous influence on numbers and kinds of organisms living there. Stream bottom types are usually listed in the following order of decreasing productivity: rubble, gravel, sand, and bedrock. There are conflicting data in regard to the importance of silt. Needham (1929) and Pate (1932) found silt to be the most productive substrate type while later Pate (1933) found that small rubble actually exceeded silt in productivity.

In Sagehen Creek, silt was clearly the most productive stream bottom type studied in terms of numbers and weights of organisms, and gravel was the least productive. Average standing crops of bottom organisms from stream and pond habitats indicate the following sequence in decreasing productivity: beaver pond, stream silt, rubble between beaver ponds, rubble in stream, and gravel in stream.

Utilization of Food by Trout

It has been shown that the beaver ponds contained greater numbers and weights of bottom organisms than did the stream.

TABLE 2.—NUMBERS OF BOTTOM ORGANISMS PER SQUARE FOOT COLLECTED AT BEAVER POND AND STREAM SAMPLE STATIONS IN SAGEHEN CREEK (Annual averages listed)

Organisms[1]	STREAM STATIONS				POND STATIONS	
	B1	B2	B5	B6[2]	B3	B4
Nematoda a.					0.3	0.5
Oligochaeta a.	1.3	2.3	0.6	35.3	37.4	55.9
Hydracarina a.	0.9	1.4	0.8	1.3	0.8	1.5
Pteronarcella n.	0.1					
Pteronarcys n.			0.1			
Peltoperla n.	0.5		0.1			
Nemoura n.	3.6	1.3	21.6		1.0	0.3
Capnia n.			0.5			
Eucapnosis n.	0.1					
Acroneuria n.	0.1	0.9	0.8			
Isoperla n.	0.4	0.1				
Arcynopteryx n.	1.0	3.6	1.4			0.3
Isogenus n.	0.1	0.8	0.8			
Alloperla n.	28.5	10.0	4.0	0.7	0.5	0.8
Paraperla n.			0.4			
Rhithrogena n.	11.1	3.6	2.4			
Cinygmula n.	38.3	21.9	7.9			
Iron n.	0.5	1.4	1.4			
Ironodes n.			0.1			
Siphlonurus n.		3.3				
Paraleptophlebia n.	1.3	2.5	4.6			
Ephemerella levis n.	5.9	8.1	3.5			1.8
E. tibialis n.	0.3	0.1	0.8			
E. doddsi n.	1.1	2.5	0.3			
E. flavilinea n.	0.6	1.8	1.0			0.5
E. coloradensis n.	0.8	1.1	0.3			
E. micheneri n.			0.1			0.3
E. delantala n.	2.5	0.9				
E. cognata n.	2.4	1.4	0.4			0.8
E. soquele n.	0.9		0.5			
E. hecuba n.		0.3				
Bactis n.	1.5	2.9	4.1			
Sialis l.	0.1		3.3	30.0	64.1	28.9
Rhyacophila l.	2.9	5.1	0.4		0.5	0.3
Glossosoma l.	9.0	34.9	6.5		0.3	
Glossosoma p.	0.1	0.6			0.3	
Agapetus l.	4.6	8.5	0.6			
Chimarra l.		0.1				
Wormaldia l.	0.1	1.0	0.1			
Psychomyiidae l.		0.3				
Hydropsyche l.	0.4	4.1	6.0			0.3
Hyropsychidae p.	0.1					
Hydroptila l.			0.6		5.0	12.0
Neophylax l.	3.0	3.0	3.3			
Limnephilidae A l.				0.7	0.3	
Limnephilidae B l.	4.0	3.3	1.3			
Limnephilidae C l.			0.1	4.7		0.3
Limnephilidae D l.	0.3					
Limnephilidae E l.	0.3	0.3	0.3			
Limnephilidae F l.	0.3	0.3				
Limnephilidae p.	0.5	0.8	0.9			
Heteroplectron l.	0.1	1.1	0.9	2.0	8.5	1.5
Micrasema l.	1.4	2.5	0.3			
Agabinus l.		0.1				0.3
Helophorus a.		0.1				
Paracymus a.			0.1			
Zaitzevia a.	4.0	1.3	0.3	0.7		
Zaitzevia l.	4.5	3.6	0.9		0.3	0.3
Narpus a.	6.8	2.4	0.8			
Narpus l.	0.3	0.3	0.4	0.7		
Lara a.					0.3	
Tipula l.						0.8
Antocha l.	0.8	11.3	5.9			

TABLE 2.—Continued

Organisms[1]	STREAM STATIONS				POND STATIONS	
	B1	B2	B5	B6[2]	B3	B4
Dicranota l.			0.3			
Erioptera l.					0.3	0.3
Hexatoma A l.		0.1	0.1	3.3	0.8	1.5
Hexatoma B l.	0.1		0.1	0.7		
Limnophila l.	0.1					
Tipulidae l.	0.3	0.4				
Liriope l.			1.1	108.0	1.6	4.8
Pericoma l.	12.0	5.1		4.0		
Simuliidae l.	0.8	0.3				
Simuliidae p.	0.1	0.1	0.1			
Chironomidae A l.				160.7	697.5	1,258.9
Chironomidae B l.				442.0	262.3	209.0
Chironomidae C l.				32.7	167.3	6.3
Chironomidae D l.	8.6	24.6	94.9	4.7		2.5
Chironomidae E l.				10.0	2.3	4.5
Chironomidae l.	8.9	23.3	123.6		0.3	0.3
Paratendipes p.					0.6	0.5
Prodiamesa p.					0.4	
Tanytarsus p.					1.0	0.3
Hydrobaenus A p.	0.3		5.3			
Hydrobaenus B p.		0.3	2.6			
Diamesa p.			0.3			
Cricotopus p.			2.0			
Pelopia p.			0.8			
Chironomidae p.	0.1		0.1		0.3	
Palpomyia l.	0.3	0.4	0.4	38.0	9.3	17.5
Chrysops l.		0.1		0.7	6.5	11.5
Tabanus l.				0.7		
Empididae l.						0.3
Unident. l. and p.		1.0				1.3
Pisidium a.	1.3	0.9	2.6	276.7	466.6	617.8
Physa a.			0.1			1.8
Gyraulus a.	0.1			0.7	0.3	2.1
Totals	180.4	213.8	325.9	1,159.0	1,737.0	2,248.6
Numbers of samples	8	8	8	6	20	20

[1] a, adult; n, nymph; l, larva; p, pupa.
[2] No sample was taken at B6 in winter.

Here, an attempt will be made to determine whether or not trout were actually utilizing the more abundant foods present in the ponds, and the relative roles of bottom fauna and drift food in the diet of the trout.

Stomachs from 142 brook, brown, and rainbow trout were obtained from stream and pond sites during the year. Angling and electric shocking were used to collect the trout. Organisms in stomachs were identified to the same taxonomic level as in bottom samples and are listed in Table 3. Adult insects not present in bottom samples were grouped as "drift."

Kinds of bottom organisms eaten by trout.—Trout from the ponds contained 72 kinds of organisms whereas stream trout contained 61. Since there was a greater variety of organisms in the stream habitat, the reverse of the above would have been expected. However, many stream forms were eaten by pond trout and a few pond forms were eaten by stream trout. Some stream organisms found in abundance in pond trout were *Cinygmula*, *Paraleptophlebia*, and *Baetis* nymphs, *Neophylax*, *Micrasema*, and simuliid larvae. Pond organisms found in stream trout were Limnephilidae A larvae and Nematoda.

Clearly there is some mechanism of food exchange between ponds and stream. One possibility is that organisms are dislodged

from their homes and float from one habitat to the other. Also, the trout themselves may move between habitats. Short riffles often occur between ponds and it is likely that trout from the downstream ponds enter these areas to feed.

In July of 1955, a two-way fish trap was placed at the head of Pond 13 (Weir II-A in Fig. 2) to determine the extent of trout movement at that time. During a 3-week period, only two trout were caught by the traps. It is concluded that very little movement occurred into or out of the ponds in summer. There are of course seasonal movements associated with spawning activities in spring and autumn.

Numbers of bottom organisms eaten by trout.—In the 142 stomachs analyzed, 7,897 bottom organisms were classified for an average of 56 per stomach. More organisms were present, but were too disintegrated for identification.

Stomachs taken during the summer months contained an average of only 15 bottom organisms. This apparent low food intake in summer correlated with the low numbers in the bottom samples at that season. However, a trout's metabolism is highest in summer and a high intake of food at this season would seem to be essential. It is known that the digestive rate in trout increases with an increase in water temperature (Hess and Rainwater, 1939; Reimers, 1957). Therefore, a higher intake of food in summer by the Sagehen trout may have occurred, even though the number of organisms recognizable at any one time was low.

On the assumption of equal availability of pond- and stream-bottom organisms, an interesting comparison may be made. Brown and brook trout from the ponds contained an average of over two and four times as many bottom organisms, respectively, as did their counterparts from the stream. The reverse is evident with rainbow trout, since they contained over twice as many bottom organisms in the stream as they did in the ponds. Perhaps this species difference in feeding accounts for the observation that brook and brown trout often do well in ponds whereas rainbow trout usually do better in stream situations.

Selection or availability of bottom organisms to trout.—To this point no consideration has been given to the numbers of different kinds of organisms eaten by trout in relation to their abundance in the bottom fauna. In an attempt to relate these two phenomena, the "forage ratio" of Hess and Swartz (1941) is employed. This ratio is determined by the following formula:

$$\text{Forage ratio} = \frac{\frac{n}{N}}{\frac{n^1}{N^1}}$$

where n = the number of any given organism in the stomachs, N = the total number of organisms in the stomachs, n^1 = the number of the same organism in the bottom samples, and N^1 = the total number of food organisms in the bottom samples. A forage ratio of 1 indicates that a particular organism occurs in the stomachs in the same frequency as it occurs in the bottom samples, and that the trout are eating it at random. A ratio of more than 1 indicates that the organism is either being selected by the trout or is readily available; a ratio of less than 1 indicates that the trout are not selecting the organism or that it is not readily available.

In using the forage ratio, it is assumed that organisms are equally available to the sampling device and the fish, and that bottom foods and stomachs are adequately sampled. These assumptions may not be entirely justified, but the use of this ratio is still the best method available for relating foods present in a habitat to foods eaten by fish. Forage ratios for the more important organisms will be considered here.

1. Important pond organisms: The most numerous organisms in the pond bottom and in the stomachs of pond trout were immature midges (Chironomidae, Diptera). If all seasons, trout species, and genera of chironomids are grouped, a forage ratio of 0.8 is derived. In reality, trout ate more midges than were recorded since these are

small, rapidly disintegrating forms which are often difficult to recognize. Midge larvae live buried in the silt, and in order for a forage ratio as high as 0.8 to exist, trout must be seeking these forms for food. Pate (1932) reported that trout were observed rooting in the bottom silt and eating midge larvae as they floated away.

The clam *Pisidium* was second in abundance in the pond bottom fauna but only three individuals appeared in all the stomachs.

Although numerous in the pond, oligochaetes were found in only two pond trout. It may be that more were eaten, but that they were too soft-bodied to remain recognizable for long in the stomachs. They, like clams, were largely unavailable and unselected.

Sialis larvae were eaten mainly by brown trout in winter and spring, the forage ratios being 1.3 and 3.5, respectively. These hellgrammites crawl around and are more available to trout than are quiescent forms living in the substrate. Their value as food is probably high since individual larvae are large.

All trout from ponds except winter rainbows ate *Palpomyia* larvae at all seasons in fair numbers. The forage ratio for summer brook trout was a high 10.1. These delicate dipterans are even smaller than midges and undoubtedly more were eaten than were recorded. Because of their small size, they are of only moderate food value to trout.

The trichopteran larva *Heteroplectron* was present in fair numbers in the pond bottom and was eaten by all pond trout. Brook trout in summer made the most use of this large, available caddis worm (forage ratio, 10.1). Housed in a hollow stick, it crawls about on the pond floor.

Brown trout ate many *Liriope* larvae (Diptera) in winter and spring and forage ratios were high, 19.1 and 22.8, respectively. These rather large, fleshy larvae should be of considerable food value to brown trout.

The two snails, *Gyraulus* and *Physa*, were not numerous in the bottom fauna, but were certainly selected by brown and brook trout. In spring, forage ratios for *Physa* eaten by brook and brown trout were 91.8 and 81.8, respectively. Summer forage ratios for *Gyraulus* consumed by brook and brown trout were 10.2 and 721. These two mollusks, especially the large *Physa*, appear to be very important trout foods.

2. Important stream organisms: In the stream as in the ponds, immature chironomids were the most important bottom organisms. The forage ratio for stream midges eaten by all trout at all seasons was 1.1.

The ephemeropteran *Cinygmula*, most important in the bottom fauna, was taken by trout in winter and spring in moderate numbers (forage ratio for spring rainbows, 0.4). These nymphs should be readily available to trout, but apparently were not selected.

Glossosoma trichopteran larvae were eaten by rainbows at all seasons, but principally in spring (forage ratio, 0.7). Spring and summer brook trout also ate this form, the forage ratio being a high 5.7 in summer. *Glossosoma* larvae live in sand cases attached to rocks and are moderately available to trout.

Although present in good numbers in the bottom fauna and quite available, *Alloperla* nymphs (Plecoptera) were almost untouched by the trout. A few nymphs turned up in brown and rainbow stomachs, but forage ratios were very low.

The abundant *Ephemerella* nymphs (Ephemeroptera) were eaten by all trout, especially rainbows in spring (forage ratio, 1.2).

The plecopteran *Nemoura* was eaten by all trout in winter and spring. Particular attention was paid the nymphs by winter rainbows (forage ratio, 1.2). This form should be available, since it crawls about on rocks.

Neophylax trichopteran larvae were eaten by all trout, particularly brown trout (winter forage ratio, 40.0). These larvae, living in gravel cases, are moderately available and certainly selected. Because they are large and fleshy, their food value would be high.

In summary, brook and brown trout living in ponds were making good use of the

TABLE 3.—NUMBERS OF ORGANISMS IN 142 TROUT STOMACHS COLLECTED FROM POND AND STREAM AREAS OF SAGEHEN CREEK

Organisms[1]	STREAM RAINBOWS				POND RAINBOWS			STREAM BROWNS			POND BROWNS			STREAM BROOKS			POND BROOKS		
	W[2]	Sp	Su	F	W	Sp	Su	W	Su	F	W	Sp	Su	W	Sp	Su	W	Sp	Su
Nematoda a.	1		2	2									1						
Gordioidea a.			1																
Oligochaeta a.							1	1								2		1	
Hydracarina a.			4	1			1				1			2	1	38		4	13
Pteronarcella n.						1					1	2							
Pteronarcys n.											1							1	
Peltoperla n.	1																1		
Nemoura n.	20	45		2	103	9		3			20	1		5	3		10	57	
Capnia n.		1																	
Filipalpia n.		3			1														
Acroneuria n.		1																	
Isoperla n.	1				3	1								1			2		
Arcynopteryx n.	2							2											
Isogenus n.				1	2														
Alloperla n.	2	1	1	1	10			1			5	1					14		
Rhithrogena n.		5			9						2	1		1	2		3	2	
Cinygmula n.	12	51			28	5		6			11			2	8		12	6	
Iron n.		5			1	1		1			1	2							
Ironodes n.		5			2						1			1	1				
Ameletus n.	5										5	2		3					
Paraleptophlebia n.	16	9	2	1	40			6		1	28	2		3		1	5	7	1
Ephemerella levis n.	6	7			9			2			10	1					11	2	1
E. tibialis n.		7			1	1		1							1				
E. doddsi n.	3	10	1									1							
E. flavilinea n.	2	4		7							1	5							
E. coloradensis n.	1	5		1								2						1	
E. delantala n.						3													
E. cognata n.							1												
Ephemerella n.		3	1	2			1			1		3					1		1
Baetis n.	8	27	2	2	16	1					2	1	1		1		2	7	1
Baetidae n.						1													
Sialis l.	4	3			1		1	3			39	63	2				1	4	1
Rhyacophila l.	1	21	3	2	2	1	1				4	4						6	2
Glossosoma l.	8	46	1	10	1	2									3	6	1		
Glossosoma p.						4													2
Agapetus l.			3																
Hydropsyche l.	2	4	1	1								2					1	1	
Neophylax l.	7	3	5	27	1	2	1	12	2	15	46	5			1	2		12	3

TABLE 3.—Continued

Organisms[1]	STREAM RAINBOWS				POND RAINBOWS			STREAM BROWNS			POND BROWNS			STREAM BROOKS			POND BROOKS		
	W[2]	Sp	Su	F	W	Sp	Su	W	Su	F	W	Sp	Su	W	Sp	Su	W	Sp	Su
Limnephilidae A l.									7										6
Limnephilidae B l.		1	61	13						7						85			
Limnephilidae C l.		2	1					3		2	6	2			2		4	1	
Limnephilidae E l.	1	10		1										1					
Limnephilidae F l.	1	226													106				
Limnephilidae G l.	6		12					2	1			3	2		5	4		8	3
Limnephilidae H l.												3							
Limnephilidae l.							6									1			
Limnephilidae p.		26				23	2					34							
Heteroplectron l.			7	4			1	3	2		6	2				3	4		2
Lepidostoma l.			1										2					1	3
Micrasema l.	14	35	15	11	4	3	14			1	1	6		3	33	16	2	15	1
Trichoptera p.		316	71	8		1						4				6			53
Agabinus l.				1								2							
Helophorus a.			1	1	1								1					2	
Paracymus a.		3	1			1													1
Zaitzevia a.							6												
Narpus a.							5												
Lara l.																	1		
Tipula l.					1						1	1							
Prionocera l.					1						2								
Antocha l.	2				1														
Hexatoma B l.		2																	
Tipulidae A l.		4	1					1				1			1				
Tipulidae p.												3							1
Liriope l.	1	1									54	9							
Pericoma l.												1							
Simuliidae l.	1	216	6		70	9					29	7			5		3	78	
Simuliidae p.	2	1										1			8			11	
Chironomidae A l.					71	25	42				884	317	4				142	229	44
Chironomidae B l.					18	2					49	7					14	8	10
Chironomidae C l.											7							2	
Chironomidae D l.	159	20	2	1	2						2	3		16	1	1	764	14	1
Chironomidae l.	496	65	37	4				95						69	2	7			
Paratendipes p.			1										2						
Tanytarsus p.						9						15							
Hydrobaenus p.						45		1											
Diamesa p.	6							4											

TABLE 3.—Continued

Organisms[1]	STREAM RAINBOWS				POND RAINBOWS			STREAM BROWNS			POND BROWNS			STREAM BROOKS			POND BROOKS		
	W[2]	Sp	Su	F	W	Sp	Su	W	Su	F	W	Sp	Su	W	Sp	Su	W	Sp	Su
Cricotopus p.	68	1	1	4				126				2		39		1			
Chironomidae p.	132	8	9	3			9				2	72	19	10		17	60	178	4
Palpomyia l.	4	3	4			1	1				5	3	2				3	14	6
Chrysops l.												1	3						
Tabanus l.			4																
Empididae l.							1												
Pisidium a.											1							1	1
Physa a.			2								1	11	3					14	3
Gyraulus a.												2	32					6	1
Salmo a.											1								
Cottus a.															2			1	
Total organisms	995	1,206	264	111	399	151	94	273	12	27	1,229	610	74	156	186	190	1,061	694	165
No. of stomachs	10	10	10	8	10	3	5	4	2	1	8	10	12	4	7	14	4	10	10
No. of bottom organisms per stomach	99	121	26	14	40	50	19	68	6	27	154	61	6	39	27	14	265	69	17
Drift organisms	4	41	327	49	2	20	84		43	5	2	27	168	1	1	120		28	69
Grand total	999	1,247	591	160	401	171	178	273	55	32	1,231	637	242	157	187	310	1,061	722	234
Total no. of organisms per stomach	100	125	59	20	40	57	36	68	28	32	154	64	20	39	27	22	265	72	23
Avg. total length of trout (mm.)	169	173	179	176	177	204	169	180	207	152	210	238	217	148	174	144	160	152	161

[1] a, adult; n, nymph; l, larva; p, pupa.
[2] W, winter; Sp, spring; Su, summer; F, fall.

abundant pond bottom fauna whereas in the stream, rainbow trout were utilizing bottom fauna to the greatest extent.

Neill (1938) states that brown trout feed on the whole range of animals present, taking them in proportion to their accessibility and representation in the environment. This conclusion cannot be supported by this study, since some seemingly unavailable organisms were eaten by trout in large numbers and some common forms were used scarcely at all. Allen and Claussen (1960) also found selective feeding by brook trout in a Wyoming beaver pond. There seems to be a definite element of selection in the foraging habits of trout.

Drift organisms in the diet of trout.—Drift organisms, or those not part of the bottom fauna, represented about half of the summer diet of all trout combined (Table 3). A few drift items were consumed in spring, but almost none were eaten in winter. The over-all average contribution of drift to the diet of Sagehen trout—pond and stream samples combined—was 11 percent.

When the species of trout are considered separately, it appears that brown trout depended more on drift in summer than did the other trouts (Table 3). On a numerical basis, drift accounted for 78 and 69 percent of the brown trout's summer food in stream and pond respectively. Brook trout depended least on drift food since 39 and 29 percent of its food in stream and pond was drift, whereas rainbow trout consumed an intermediate amount of these foods. All trout living in the stream depended more on drift foods than did those inhabiting ponds.

Most of the adult insects grouped as drift lived in the bottoms of stream and pond before they emerged. This further minimizes the contribution of strictly terrestrial insects to the diet of Sagehen trout. The trout of this stream live largely on aquatic insects.

FISH POPULATIONS IN BEAVER POND AND STREAM AREAS

Fish populations in Pond 14 and in stream sections at the Sagehen Creek Project and near B6 (Figs. 1 and 2) were censused each August between 1954 and 1957. The pond measured 221 ft. in length and had a surface area of 0.0555 a. It was atypical in that it was long and narrow, but it was chosen for sampling because the stream could be diverted around it. The stream sections at the Project and near B6 had lengths of 149 and 150 ft. and surface areas of 0.0391 and 0.0429 a., respectively.

Populations were measured by the diversion and draining method described by Needham and Rayner (1939). The stream was diverted, the pools pumped dry, and the fish were removed, measured to total length, weighed, and marked with jaw tags. They were returned to the stream when water was restored in the channel. This method is most accurate for determining fish populations, since nearly all fish over 25 mm. in length are captured.

Trout Populations

Species and numbers.—The total numbers of each trout species sampled during the entire study in the beaver pond and in an equal length of the combined stream sections are given in Table 4. Rainbow trout were dominant in both habitats and accounted for slightly over one-half the population of each. Brook trout were second in abundance and brown trout were least abundant. The unusual paucity of brown trout in the pond may be due to the fact that it lies near the upper altitudinal limit of the range of this species.

Average numbers of trout in the pond

TABLE 4.—TOTAL NUMBERS OF TROUT PRESENT IN BEAVER POND 14 AND IN THE COMBINED STREAM SECTIONS OF SAGEHEN CREEK FROM 1954 TO 1957 (221 ft. of each habitat compared)

Trout Species	Beaver Pond 14		Combined Stream Sections	
	Number	Percentage	Number	Percentage
Brown trout	39	24	21	13
Brook trout	42	25	52	32
Rainbow trout	85	51	88	55
Totals	166	100	161	100

and in an equal length of combined stream sections for the 4-yr. period were similar, being 41 and 40, respectively. On a trout-per-acre basis, averages of 747 and 664 were determined for pond and combined stream sections, respectively (differences not significant at 5 percent level). In contrast, Huey and Wolfrum (1956) found four times as many trout in pond as in comparable stream sections. They used electric shocking for censusing, and since this method misses many small trout so numerous in stream sections, their low figure for stream trout may be exaggerated.

Size of trout.—Whereas there were about as many trout in the stream as in the pond, the pond fish proved to be much larger. Between 1954 and 1957, there were 30 trout over 200 mm. long in the pond, but only 11 trout of this length occurred in an equal length of combined stream sections. (One 628-mm. brown trout from the pond was the largest trout ever recorded in Sagehen Creek.) The average total length of trout in the pond was 147 mm. whereas that in the stream was only 110 mm. (difference significant at 1 percent level). Rutherford (1955) also found longer brook trout in beaver ponds than in stream areas in Colorado. On the other hand, the Sagehen stream sections contained more fry. Forty trout under 75 mm. long were present in the pond; only 58 of these small trout were taken in the combined stream sections.

The average weight of trout in the pond was more than five times greater than that for the stream. Pond fish averaged 117 g. in weight while stream fish averaged only 22 g. The 4-yr. average total weight of all trout in the pond was 10.7 lb. (193 lb./a.) as contrasted to only 2.0 lb. (32 lb./a.) in an equal length of the combined stream sections. All weight differences are significant at the 1 percent level.

During the 4 study years, the standing crop of trout in the pond showed a general decline (Fig. 6). The sharp decline in 1956 also occurred in the stream and was doubtless due largely to the devastating flood of December 1955. The relatively greater decrease in total weight of trout in the pond

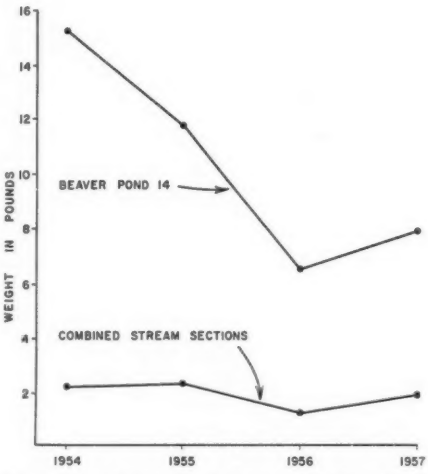

FIG. 6. Total weights of trout in equal lengths of beaver pond and stream sections of Sagehen Creek.

as compared to the stream was due to the exclusion of fishing from the stream section at the Sagehen Creek Project during the latter 2 years and to the fact that the pond was aging. It has often been noted that beaver ponds age and become less productive in time.

Removal by angling.—The greater number of larger sized trout in the ponds was reflected by a greater relative take of pond fish by anglers. A creel census of the upper 6 mi. of Sagehen Creek, including the Rockslide and Upper Beaver Colonies, was taken on randomly selected days during each fishing season. This survey revealed that 31 percent of the 4-yr. catch was taken from the two beaver colonies which occupied only 10 percent of the length of the census area. Certainly, the relatively higher catch from the ponds is at least in part the result of the larger trout populations there, although differential fishing pressure between pond and stream may also be involved. Bailey and Stephens (1951) report a situation in a West Virginia stream where over 4 times as many trout were caught after the stream had been ponded by beavers.

Differential removal of pond and stream trout means that the weight comparisons

TABLE 5.—TOTAL NUMBERS AND WEIGHTS OF SCULPINS PRESENT IN BEAVER POND 14 AND IN THE COMBINED STREAM SECTIONS OF SAGEHEN CREEK (221 ft. of each habitat compared)

Year	Pond 14		Combined Stream Sections	
	Numbers	Pounds	Numbers	Pounds
1954	366	1.85	695	4.28
1955	225	1.28	381	2.66
1956	264	1.31	370	2.51
1957	444	1.69	604	3.93
Average	325	1.53	513	3.35

in Fig. 6 would show even more contrast in the absence of angling.

Sculpin Populations

The standing crop (numbers and weights) of sculpins (*Cottus beldingii* Eigenmann and Eigenmann) in the stream was significantly higher than that in the pond at the 5 percent level (Table 5). This situation is consonant with the known preference of sculpins for riffles.

Relatively high sculpin populations in 1954 were followed by a low in 1955 (pond) or 1956 (stream) and a marked increase in 1957. Seemingly the flood of 1955 had an adverse effect on sculpins as well as on trout.

Dietsch (1958) found that both sculpins and brook trout in Sagehen Creek eat considerable amounts of immature Diptera, Trichoptera, Ephemeroptera, and Plecoptera. The present investigation indicates that rainbow and brown trout also rely heavily on the same insect orders for food. Large trout eat sculpins (Table 3) and sculpins eat some trout eggs (Dietsch, 1958), but food competition is probably the most important interaction.

EFFECTS OF POND REMOVAL UPON TROUT HABITAT, FOOD, AND POPULATION

The flood of December 1955 washed out most of the Rockslide beaver dams and provided an excellent opportunity to assess the effects of dam removal upon trout foods and populations.

Post-flood sampling was delayed 1½ yr. to permit the Rockslide area to re-establish itself as a typical stream. In July 1957, two 1-sq.-ft. samples of the bottom faunas at B3, B4, and B5 were taken with a Surber sampler and analyzed in the fashion already described. It will be recalled that Stations B3 and B4 were sampled with an Ekman dredge in July 1954, when the dams were intact.

The electric-shocking method, described by Haskell (1940), was used to determine the trout populations present in the area occupied by ponds 6N, 6S, 7N, and 7S in July of 1955 and 1957. A portable generator delivering 110 v. and 18.2 amp. of direct current was used to supply electricity. Two separate drives were made with the shocker during each sampling period.

Before the electro-fishing method was used, it was compared to the diversion and draining method to appraise its effectiveness. After the 1954 fish census of Pond 14, the stop nets were left in position. The trout population was then sampled with the shocker. Forty-two of the 61 trout replaced in the pond were taken with the shocker, a 69 percent recovery. Nearly all the trout missed by the shocker were small, since only 1 trout over 150 mm. long was not recaptured. Other reports show that shocking success is greater with larger than with smaller trout (Huey and Wolfrum, 1956).

Changes in Habitat and Bottom Fauna

Several physical changes in the habitat occurred after the dams washed away. The aquatic environment shrank in depth, width, volume, and area but water velocity increased from almost none to an average of 1.8 ft./sec. at B3 and B4. Most of the silt in the ponds washed downstream and left a rubble and gravel stream bed.

With the change to a stream habitat came a sevenfold average reduction (2.29 to 0.31 g./sq. ft.) in weight of bottom organisms at Stations B3 and B4. This difference is significant at the 1 percent level. That this decrease was due to dam removal and not merely to changing conditions between years is indicated by a stream station (B5) which had similar weights (0.40 and 0.43 g./sq. ft.) of bottom organisms at

TABLE 6.—NUMBERS OF TROUT PRESENT IN THE AREA ENCOMPASSED BY FOUR ROCKSLIDE BEAVER PONDS ON SAGEHEN CREEK BEFORE AND AFTER THE REMOVAL OF THE DAMS

Trout Species	Before Dam Removal		After Dam Removal	
	Number	Percentage	Number	Percentage
Brown trout	76	74	6	31
Brook trout	24	23	3	16
Rainbow trout	3	3	10	53
Totals	103	100	19	100

each period. Decrease in total standing crop at the areas occupied by ponds 6N and 8 was computed to be 22-fold. The difference here is much greater than that for weight per unit area since there was a notable decrease in water area after the dams washed out.

Changes in Trout Populations

A marked change in the species composition and standing crop of trout inhabiting the area encompassed by Rockslide Ponds 6N, 6S, 7N, and 7S occurred after the removal of the dams. These ponds supported mostly brown trout, but after the washout, rainbow trout replaced brown trout as the dominant form and brook trout became least abundant (Table 6). A pre-flood population of 103 trout totaling 8.3 lb. decreased drastically to only 19 trout totaling 2.7 lb. after the washout changed ponds to a stream (Fig. 7). Neff (1957) reported a large number of brook trout in an active Colorado beaver colony and only a few trout in beaver-abandoned streams where the ponds had drained.

A stream section, little affected by the flood, had been sampled concurrently with the Rockslide site and was used as a control. In this section, 104 trout were shocked in July 1955 and a nearly equal number (108) was taken in July 1957. Therefore, the decrease in the trout population in the four Rockslide ponds must be attributed to the removal of the dams and not merely to yearly fluctuation.

BEAVER DAMS AND TROUT MIGRATIONS

Many publications on beaver-trout relationships mention the possible blocking of migrating trout by beaver dams, but most of these discussions are of a speculative nature. In order to determine to what extent beaver dams affected trout spawning success in Sagehen Creek, a study of migrating trout was undertaken.

Critical locations throughout the Rockslide Colony were selected for the placement of fish weirs, which were installed in October of 1954. One weir was located at each end of the colony and five others were placed among the ponds where the topography permitted (Figs. 1 and 2). The weirs consisted of a picket fence with half-inch openings bordered by box-type traps with V-shaped entrances. Daily visits were made to the weirs during the fall and captured trout were measured, jaw-tagged, and placed on the side of the weir toward which they were headed. Electric shocking and a creel census were also carried out in the Rockslide area between October 1954 and September 1955 to expedite tagging and to determine movements.

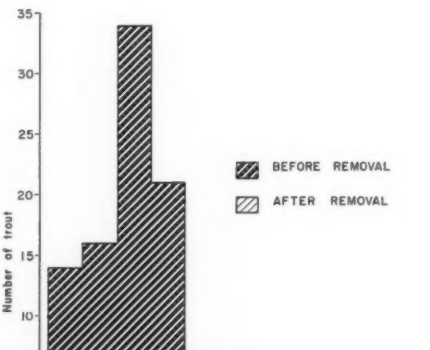

FIG. 7. Numbers of trout in four Rockslide beaver ponds on Sagehen Creek before and after the dams were washed out.

TABLE 7.—NUMBERS OF TROUT KNOWN TO CROSS ONE OR MORE BEAVER DAMS DURING THE MIGRATION STUDY ON SAGEHEN CREEK

Direction of Movement	Season	Brown Trout	Brook Trout	Rainbow Trout	Total
Upstream	Fall	3	0	0	3
	Spring	8	3	1	12
	Summer	3	0	0	3
	All	14	3	1	18
Downstream	Fall	1	1	0	2
	Spring	9	1	4	14
	Summer	3	0	0	3
	All	13	2	4	19
	Total	27	5	5	37

The dams in the Rockslide Colony were constructed of willow and aspen sticks, mostly under 3 in. in diameter, and plastered with silt and sod. They ranged in height from 2.5 to 5 ft. (average, 3.5 ft.) and in length from 14 to 200 ft. (average, 63 ft.).

The Barrier Effect of Beaver Dams upon Migrating Trout

Throughout the migration study, 443 trout in the Rockslide area were tagged. Thirty-seven of these trout were known to cross one or more dams (Table 7), a fact that gave an 8 percent return. No doubt many more trout crossed dams, but were not detected. Crossing down over dams should be easier than crossing up over dams and it is interesting that almost equal numbers of trout crossed in each direction. Only 5 trout were known to cross dams during the fall, but 26 crossed dams during the winter and spring and 6 crossed during the summer. Higher waters in spring presumably permitted easier movement at that season. Four times as many trout (109) were caught moving upstream through the traps as were taken going downstream (24), a tendency that agrees with most studies.

The three kinds of trout exhibited differences in dam-crossing proclivities. Brown trout were most inclined to cross dams. This does not merely reflect the greater number of browns tagged, since the ratio of browns to rainbows and brooks tagged (247:196) is significantly less (5 percent level) than the ratio of browns to rainbows and brooks known to cross dams (27:10). Five rainbow trout, 4 brook trout, and 17 brown trout crossed dams in the spring. This was anticipated for the spring-spawning rainbows, but not for the fall-spawning brooks and browns. Rainbow trout known to traverse dams showed great facility in surmounting these obstacles since four rainbows crossed down over Dams 1 through 14 and one rainbow crossed up over Dams 7 through 14.

All dams were crossed in both directions by one or more trout except Dam 1, which was not known to be negotiated by any upward-moving trout. Salyer (1935) reported that trout did not pass upstream over ordinary beaver dams, a statement that is not supported by my data.

The question may be raised as to how trout manage to cross dams. Where present, side channels provide easy avenues along which trout may circumvent dams. Simply jumping up or down over the dam is the most obvious method. Hodgdon and Hunt (1953) suggest that this could be done most easily at the places where beavers cross dams, since small waterfalls are often present there. Trout may actually penetrate some dams by following the small trickles that percolate through them and by wiggling up through the interwoven sticks and mud. P. R. Needham (personal communication) saw a trout push upstream through a sod dam at the Sagehen Creek observation tank in such a manner.

It may be concluded that some trout can and do cross up and down over many types of beaver dams at all seasons and that the dams are not complete barriers to migration, particularly in spring. It is likely that they are partial barriers in the fall, as concentrations of trout were observed below some of the larger dams at that season.

The important question, I think, is not whether the dams are barriers to migrating trout, but whether they actually inhibit reproduction to the extent that adult populations are lowered. I cannot believe that they do because: 1) it has been demon-

strated that there is at least some crossing of dams by trout; 2) many trout spawn in the short riffles between ponds; on November 6, 1954, 37 redds were observed between Dams 1 and 13, a section of almost continuous beaver dams (Fig. 2); 3) it has been shown that the ponds are well stocked with trout; and 4) it is not the number of eggs (within limits) that determines the number of adults resulting, but rather the survival rate of the eggs present.

BEAVER–TROUT RELATIONS IN DIFFERENT LOCALITIES

The effects of beaver on trout vary markedly in different geographic and ecologic situations.

In some sections of the United States, particularly on marginal trout waters of the midwest and east, beavers have been found to be detrimental to trout (Salyer, 1935; Reid, 1952; Adams, 1953). But many streams in others regions have provided better trout fishing as a result of beaver activity. Some California streams become virtually dry in summer and beaver ponds in these may be instrumental in maintaining permanent trout populations (Tappe, 1942). Most investigators in the Rocky Mountains have reported general benefits of beaver activity to trout (Rasmussen, 1941; Grasse and Putnam, 1950; Huey and Wolfrum, 1956). Beaver in the headwaters of some Missouri streams are restoring permanently flowing water and good fishing (Dalke, 1947). It is not surprising that studies from unlike areas often indicate grossly different conclusions.

A consideration of the home, foods, and spawning activities of the trout, and the trout populations themselves, can lead only to the conclusion that beaver are of decided benefit to trout in Sagehen Creek.

SUMMARY

A study of the effects of beaver on trout was conducted on Sagehen Creek, California, from 1954 to 1957. The purpose of the inquiry was to investigate several ways in which beavers and their activities influence the three species of trout present in the creek. Accordingly, comparisons were made between sections of the natural stream and sections that had been ponded by beavers, in regard to: 1) physico-chemical conditions; 2) production of trout foods; 3) feeding habits of the trout; and 4) populations of trout. Further, the consequences of beaver dam removal on trout foods and populations were assessed, as well as the ways beaver dams affect trout spawning activities.

Physical environment of the trout was altered measurably following construction of beaver dams. Most importantly, the substrate changed from gravel and rubble to silt, water velocities decreased, ice conditions became less severe, and the depth and area of the aquatic habitat increased. Water temperature extremes lessened in the ponds, but water chemistry was little affected.

These changes in physical environment resulted in profound changes in the bottom fauna. Although fewer different kinds of organisms were found to live in pond bottoms, much greater standing crops of organisms were living there than in the stream.

All trout relied heavily on bottom faunas for food. In summer, however, drift organisms also became important. Trout living in the stream ate stream fauna almost exclusively. Rainbows living in the ponds depended largely on stream organisms for food, but pond brook and brown trout were supported mainly by pond faunas. Foraging was not random; some organisms, though seemingly unavailable, were selected by trout in both habitats.

The higher standing crop of bottom fauna and the unique physical environment in the ponds were reflected in greater trout populations. These in turn resulted in a relatively higher catch in the ponds than in the stream.

A flood in 1955 removed most of the dams in one beaver colony. Following dam removal, there was a substantial decrease in surface area, trout food, and number of trout. Rainbows replaced browns as the dominant species.

Some marked trout crossed up and down

over most beaver dams at all seasons. There was no evidence that the barrier influence of dams depressed the level of adult trout populations.

It is concluded that beaver are of substantial benefit to trout in Sagehen Creek.

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LOSS OF WATERFOWL PRODUCTION TO TIDE FLOODS

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The possibility of waterfowl nesting losses of catastrophic proportions in certain Arctic areas has been recognized for 20 years or more. Cottam, *et al.* (1944), reporting a waterfowl reconnaissance of the Mackenzie River delta in 1940 by Gillham and Lynch, pinpoint the crux of the situation with the following account.

"There is, however, one grave and ever-present danger to the nesting success of the brant. . . . Storms may arise any time during the breeding season, driving sea tides over the low nesting islands. Soper (1930) mentions storms as a factor affecting populations of the blue goose. Forbush (1925) suggests that the yearly numerical fluctuations of wintering Atlantic brant denote destruction of nests and young by Arctic storms. Gillham and Lynch found the brant in the Mackenzie region to have had a favorable nesting season in 1940, but a storm had disrupted early nests of the snow goose on the islands under observation. Many "two-story" goose nests were found on low areas with one or two eggs in the bottom compartment. Numerous stray eggs were seen, some along the drift line of storm wrack, suggesting that they had been washed out of early nests. Others were dropped at random by laying females whose nests had been destroyed. These geese renested, however, and brought off a successful hatch during the first week in July. As most brant nests hatched between July 10 and 13, it was believed that the nesting season for this bird did not get under way until after the storm. Had this storm occurred when the nesting season was well advanced, wholesale destruction of brant nests and young doubtless would have resulted, because Arctic summers are too short to permit renesting when the first nests are lost late in the season. Brant nests, furthermore, are more exposed to flooding than those of snow geese. The snow goose usually nests on the highest banks of the delta islands, whereas the brant prefers to nest on low islets where usually a rise of only 6 inches in the water level will destroy many nests."

OBJECTIVES

The purpose of this paper is to summarize two field studies in Alaska where conditions comparable to the situation cited above have been under observation.

In 1951, Sigurd T. Olson conducted a waterfowl production study on the outer Yukon-Kuskokwim Delta in western Alaska. One of the objectives of his study was to determine the effect, if any, of storm tides on the production of black brant (*Branta nigricans*) and cackling Canada geese (*Branta canadensis minima*). In 1959, Charles Trainer and Peter Shepherd conducted a waterfowl production study on the Copper River Delta in southern Alaska. One of the objectives of the latter study was to determine the factors influencing production. Through an unforeseen but fortuitous circumstance, Trainer and Shepherd had an opportunity to study in detail the effect of tide floods on egg laying and incubation. It was my privilege as their supervisor to make frequent contact during

the summer of 1959 with the project biologists and help guide their investigations.

I have taken most of the data summarized in this paper from Olson's and Trainer's progress reports. I gratefully acknowledge their cooperation and the generous use of their field data. The responsibility for this interpretation and presentation of their information is mine alone. However, Olson has critically reviewed the manuscript and agrees with the summarization.

YUKON-KUSKOKWIM DELTA

Spencer, *et al.* (1951) first reported the potential threat of a combination high tide and onshore storm to the production of black brant and cackling geese on the Yukon-Kuskokwim Delta.

Olson (1951) supplied data which clearly indicate the vulnerability to flooding of waterfowl nests on the Yukon-Kuskokwim Delta. He conducted a detailed study of the factors influencing production on the outer fringe of the delta in June and July 1951. Three plots totaling 2 sq. mi. were selected, one in each of three fairly distinct topographic zones located between the shoreline and a point about 10 mi. inland. An accurate determination was made of species composition, nesting densities and total production, mortality factors, and influence of tides in each zone. Black brant and cackling geese, both highly gregarious species and of equal abundance, comprised 81 percent of the total population. Spectacled eiders (*Lampronetta fischeri*), common eiders (*Somateria mollissma*), and Steller's eiders (*Polysticta stelleri*) made up an additional 13 percent. The remainder were white-fronted geese (*Anser albifrons*), emperor geese (*Philacte canagica*), whistling swans (*Olor columbianus*), and pintails (*Anas acuta*). On the 3 study plots, an average density of 153 nests per square mile was recorded, ranging from a high of 276 to a low of 74 nests per square mile. Brant and cacklers, the 2 most abundant species, had a hatching success of 79 and 73 percent, respectively. Of 9 white-fronted goose nests under observation, all but 1 hatched for a success of 89 percent. Brant averaged 3.5 eggs per clutch, and cacklers 4.0.

This area of specialized brant–cackling goose habitat in Alaska has subsequently been measured as approximately 500 sq. mi. in a narrow coastal belt from 8–10 mi. wide and 50–60 mi. long (Hansen and Nelson, 1957; 1959). Brant nest only on the outer two-thirds of this zone and cacklers primarily on the higher, inner two-thirds.

Olson (1951) observed no losses due to storm tides during the nesting season, although abnormally high tides did occur in July after hatching was completed. The three study areas were progressively less vulnerable to rising water with the distance inland. Measurements showed that a rise of 2 ft. above the July 7 tide would have been necessary to flood a majority of the nests on the inland study area. The middle study area would have been almost entirely covered by an additional foot of water, and nests on the outer area would have been inundated with an additional rise of 6 or 7 in. Of 49 nest sites checked in the latter plot on July 8, all were only 5 or 6 in. above the tide mark of the previous night. By that date, however, only two of the nests were still active.

Although there is always the threat of flood, it rarely occurs according to the local Eskimos. When natives were asked about flooding of nests, they always replied, "It is an old saying that the nesting grounds of the birds are never flooded during nesting time." No native of the area could remember seeing the nesting grounds flooded during May, June, or early July. They all agreed, however, that storm tides from about the middle of July through autumn created occasional flood conditions. Adams (1952) reported that a high tide on August 10, pushed by a 40–50-m.p.h. wind, covered up to 90 percent of the delta as far inland as 10 mi. in some places.

The highest tide Olson recorded in the 1951 nesting season occurred on July 15 as a result of a severe onshore wind storm. A post-storm check of the three study areas indicated that the inland plot had not been flooded significantly. The middle area had

FIG. 1. Aerial view of the Copper River Delta on the south-central Alaska coast (scale 1:15,000). This area supported 169 waterfowl nests per square mile in 1959. Note the light-colored grass/forb vegetative cover on the ridges of silt adjacent to each meandering tide channel. The darker vegetation, primarily *Carex* and *Equisetum*, is inundated with every tide of 13 ft. or more. (Photo by U. S. Forest Service.)

been partially flooded and the shoreward area almost entirely wave swept. Had this storm appeared 3 weeks earlier it would have caught incubation at its peak. On the outer area, 100 percent of the nests would have been flooded, and between 20 and 25 percent on the middle area. In spite of the Eskimo's maxim, the above data show that a serious flooding of these important nesting grounds could occur during the critical incubation period.

COPPER RIVER DELTA

Olson (1953) called attention to the vulnerability of the Copper River Delta nesting grounds following an initial production study in that area. He stated, "Extremely high tides driven by strong, onshore winds could possibly be a serious factor affecting the nesting success over more than a third of the nesting grounds on the delta." The Copper Delta is geographically small in comparison to the Yukon-Kuskokwim Delta. However, much of the "vulnerable third" referred to by Olson supports a very high nesting density of Western Canada geese (*B. c. occidentalis*) and several species of ducks.

From early May through August in 1959, Trainer and Shepherd conducted another production study on the Copper Delta. They established a 2-sq.-mi. study plot in a high density nesting area (Fig. 1). Altogether, they located nests of 224 Western Canada geese and 114 ducks of 6 species within the study area for an average of 169 waterfowl nests per square mile plus an undetermined number of shore bird nests. They had a unique opportunity to observe the mechanics of tidal flooding and to make a quantitative assessment of mortality due to flooding during the course of this study.

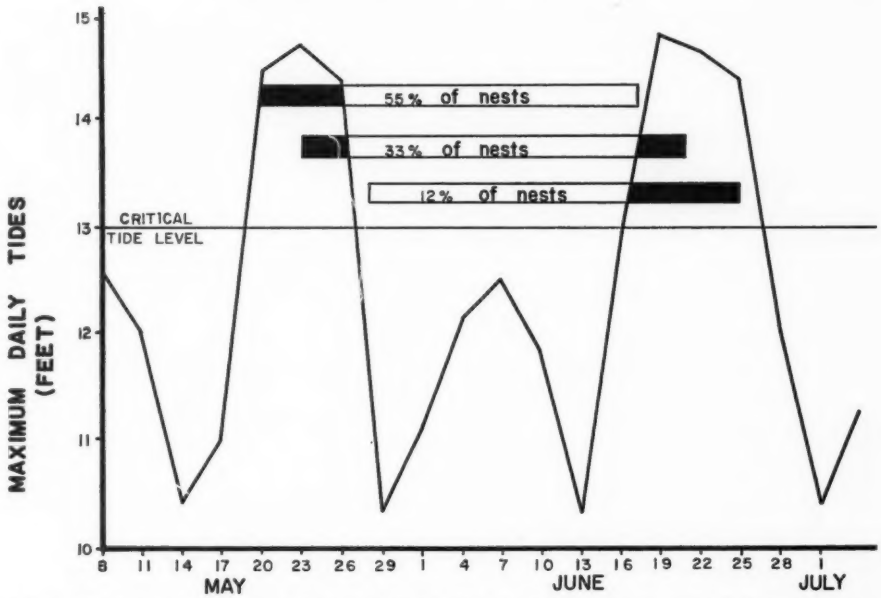

FIG. 2. The height and timing of the Copper Delta tides in relation to the progression of Canada goose incubation. Each bar in the graph spans a normal 28-day incubation period. Fifty-five percent of the incubated clutches were subjected to the May cycle only, 12 percent to the June cycle only, and 33 percent to both May and June flood tides.

The rhythm and height of the tides in the Gulf of Alaska is such that most waterfowl nesting on much of the Copper Delta cannot escape a major peak of at least one high cycle during every nesting season. As illustrated in Fig. 2, there are two high cycles each month, one of much greater magnitude than the other. These highs are staggered a week earlier each succeeding year so that the entire cycle repeats every 4 years. Regardless of whether the nesting season is "early" or "late," a span of about 40 days is required during May and June to complete a majority of the egg laying and incubation.

In 1959, tides which could have been damaging were those normal highs exceeding 13 ft. measured at the Cordova Reference Station. Between May 19 and 26, 7 tides between 13.0 and 14.8 ft. were recorded. From June 17 to 24, 7 more tides ranging from 13.2 to 14.6 ft. were recorded. During the high tide period in both May and June, the weather was fair with no strong onshore winds to drive the tides beyond normal bounds. During both months, the daily maximum tides occurred at night between 9:30 p.m. and 2:30 a.m. Most of the observations, therefore, were actually an interpretation of events following the tidal activity of the previous night.

Ridges of silt and debris, 15–20 in. higher than the critical 13-ft. level have been formed adjacent to the tidal sloughs (Fig. 1). Most of the nests of both geese and puddle ducks were built on this higher ground which varies in width from a few feet to several yards and supports a thrifty growth of woody-stemmed forbs. Ninety-seven percent of the geese and 88 percent of the puddle ducks nested on these ridges although they comprise no more than 10–15 percent of the tidal land area on the outer delta. The remainder of the flats is a

wet sedge meadow interspersed with shallow, brackish ponds utilized primarily by diving ducks.

As nests of either ducks or geese became endangered by encroaching tides, the birds hurriedly built up their nests using whatever material was available. With a 24-hr. respite before the succeeding higher tide arrived, most individuals were able to keep ahead of all but one or two of the extreme tides in each cycle. Scaup (*Aythya marila*) and canvasback (*Aythya valisineria*) built their nests as much as 18 in. above the original structures to escape the extreme June tides. Pintail nests were built up from 4–6 in. with some eggs occasionally buried beneath the new superstructure. Incubating geese denuded the area surrounding their nests of both green and dead vegetation to build their bulky structures as much as 8 in. higher than the original nests.

Of 89 goose nests visited during the peak of hatching in the June tides, 53 percent had been flooded at least once. The maximum known depth that water covered any nest was 8 in. One nest, containing 3 eggs from an original clutch of 5, was covered by 4 in. of water in the tide of June 20. Nine days later all three of these eggs hatched. In most of the nests, however, the water seeped through the bottom only high enough to soak the eggs and nest material thoroughly. There was evidence that most of the geese remained on the nest during the flood period except in extreme cases such as the 8-in. coverage cited above.

Of the 224 Canada goose nests found on the study area, 222 were followed to completion. Of the nests in which one or more eggs hatched, the success was 87.4 percent (194 nests). Hatching success of 1,017 eggs produced in the 194 nests was only 83.5 percent, however. Most of this loss probably resulted from the floods either of May or June. Of 168 unhatched eggs examined from successful nests, 9 were washed from the nest by high water. Embryonic development in 65 terminated at an early stage of incubation (probably during a May flood tide). Another 55 eggs contained fully developed embryos, 36 of which drowned after pipping. Of 30 eggs which failed to hatch from undetermined causes, some could have been flooded. Only 9 of the 168 eggs (5.4 percent) appeared to be infertile.

In comparison with Canada geese, the overall success of 132 duck nests under observation was not quite as good. Only 76.5 percent of the duck nests were successful and 80.4 percent of the 850 eggs in successful nests hatched. Avian predation accounted for the majority of losses of duck nests, only two of which were lost to flooding. Of 59 unhatched eggs examined, 29 contained dead embryos, 21 contained embryos which died early in incubation, and 9 eggs (15.3 percent) appeared infertile.

The greatest loss from flooding of both duck and goose nests was due to a lowered hatchability of the eggs rather than to total destruction of nests. Because of a longer incubation period and the time of nesting, geese were subjected more to storm tides than ducks. A great many geese endured both the May and June flood tides whereas practically all pintail and mallards (*Anas platyrhynchos*) had hatched prior to the June tides. The other species of ducks had not started to incubate until a week or more following the May tides. By May 25 when the last damaging tide in this cycle occurred, 88 percent of the geese had started to incubate. Fifty-five percent of the incubating goose nests were affected by the May flood only, 33 percent underwent both tide cycles, and 12 percent were subjected to the June tides only (Fig. 2).

DISCUSSION

Although certain groups of Arctic and sub-Arctic waterfowl such as brant, snow geese (*Chen hyperborea*), cackling geese, and others nest under precarious circumstances, they are able to adapt themselves successfully to the normal vagaries of their environment. Their very existence testifies to this. The compensations for more severe environmental limitations not imposed in southern breeding areas are few and simple. Predation is relatively light, allowing for high nesting success and good survival of young. At the present time agriculture is

non-existent and other man-induced disturbance is minimal. Many of the species involved have a longer life span and a delayed initial breeding age which gives them one complete age class as a nesting population "cushion" in case of near-total loss in any given year. As demonstrated by Canada geese and several species of ducks on the Copper Delta in 1959, the incubating birds are capable of emergency action if overtaken by normal high tides during good weather.

Perhaps the most significant facts revealed in the 1959 Copper Delta study were (1) the tenacity of incubating birds under duress, and (2) the durability of the embryos when subjected to adverse temperatures at various stages of incubation. The investigators purposely curtailed their activity during the critical 2 or 3 hr. of highest tide each night so as not to disrupt emergency repairing of the nests. Either the birds were able to maintain normal temperatures within the nests during the flood, the tolerance of temperature loss by the developing embryo was quite flexible, or the embryo was able independently to maintain its temperature. The Copper River, which drains extensive glacial fields, is characterized by a very low temperature until the summer is well advanced. Sea water near the mouth of the Copper River averages no more than 42 to 43°F. until late May, warming to 50° by late June (Robinson, 1957). A hatching success of 83 percent, if incubating eggs have been washed by water that cold, indicates a remarkable hardiness, especially if the exposure is sustained or repeated.

If the normal pattern of gradually increasing high tides over a period of several days should be accelerated or greatly accentuated by onshore winds, however, the birds would be unable to cope with the problem. Under these conditions the hypothetical "catastrophe" could become a reality. As Spencer, *et al.* (1951) pointed out, "While no trick of management will likely safeguard against the phenomena of weather we should be aware of any such catastrophe in order to safeguard, through regulations, the breeding stock for a subsequent year."

SUMMARY

The possible loss of a season's total waterfowl production under Arctic conditions in certain coastal environments has been recognized for many years. Tidal activity was studied in 1951 on the Yukon-Kuskokwim Delta where the nesting densities reached 276 nests per square mile, with a hatching success from 73 to 89 percent. In 1959 on the Copper River Delta, 338 waterfowl nests were followed to completion on an area which was covered by 2 cycles of flood-tide during the nesting period. Nests were observed in water as much as 8 in. deep. Hatching success of 1,017 eggs produced in 194 successful goose nests was 83.5 percent. Of the 850 duck eggs in successful nests, 80.4 percent hatched. The greatest loss from flooding to both ducks and geese was due to a lowered viability of the eggs rather than to total destruction of nests. Of the several species of ducks and Canada geese observed on the Copper Delta, all were capable of emergency adaptations to keep the majority of their nests built up above the encroaching water. A catastrophe to the year's production could occur, however, if these high tides were suddenly driven well above normal levels by strong onshore winds.

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FOODS AND FEEDING PATTERNS OF THE COLLARED PECCARY IN SOUTHERN ARIZONA[1]

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Little has been written on the foods of the collared peccary (*Pecari tajacu*). Jennings and Harris (1953) found that the major food taken by peccaries over most of their range in South Texas was pricklypear (*Opuntia* spp.). Knipe (1957) found that pricklypear was the staple food of most peccaries in Arizona. Neal (1959) analyzed the contents of 36 peccary stomachs and found that *Opuntia engelmannii* made up 84.5 percent of the total contents by volume.

In Arizona, peccaries are found in the desert and the adjacent desert–grassland, chaparral, and oak–grassland vegetational types on the higher mesas, foothills, and mountain sides (Knipe, 1957). Marginal range includes the lower elevations of the pine zone which occurs in the higher desert mountain ranges.

The objectives of this study were: (1) to determine the food habits of the peccary in southern Arizona, (2) to determine the effects of peccary herds on the vegetation, (3) to determine the factors influencing the duration of the feeding period, and (4) to gather information on feeding behavior. The study began in July 1957 and ended in April 1959.

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METHODS OF STUDY

Peccaries feed erratically, have seasonal food preferences, and eat plants on which utilization cannot be measured by most standard methods. Consequently, the "feeding-minutes" technique seemed feasible as a principal method of study.

The Soil Conservation Service used the feeding-minutes technique in the 1920's and 1930's to study the plants utilized by cattle and sheep on the ranges in some western states. One of the first applications of the method in the wildlife field was made by Dixon (1934) on a study of mule deer in California. Buechner (1950) used the technique for antelope in the Trans-Pecos region of Texas, and White (1957) for white-tailed deer in southern Arizona.

The feeding-minutes technique was used in this study because it shows exactly what the animal eats and when, where, and how it feeds. One "feeding-minute," as used here, is the equivalent of one peccary feeding for 1 min. on a given food item. "Con-

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tact" signifies an unspecified time period during which the animal touches the plant during the process of consuming all or any part of it.

Herds were located in the study areas by searching habitat near an abundance of feeding sign. Binoculars or spotting scopes were used to locate and observe herds. When a herd was located, it was followed and feeding minutes were recorded until the animals quit feeding or until dark. In using the feeding-minutes method, the time was recorded with a stop watch from the time of contact with the food plant to the time when the peccary stopped taking the food item. Time was recorded to the nearest 5 sec. If a sufficient amount of feeding time was recorded, it should indicate the relative importance of each plant species during each season of the year.

The rooting activity of peccaries was studied to determine the importance of underground food items in each study area and species of plants sought.

Two variations of the feeding-minutes technique were used. When the plant being fed upon could be seen, the feeding activity of the closest and most visible animal in the herd was timed as long as it was possible to do so. However, an attempt was made to record minutes on a number of individuals in order to secure a more accurate appraisal of feeding by the herd as a unit.

When it was impossible to identify the plant being fed upon, time was recorded on all contacts made by the peccary with vegetation as it fed at a specific location. With the aid of a small map, sketched while observations were being made, the feeding spot was located after the herd moved on. Feeding evidence was found to occur on several species. Sometimes it was necessary to examine all the freshly clipped and gnawed plants and to estimate the amount of time spent on each species. This technique became more valuable as field experience was acquired in reading feeding sign.

Upon location of a herd in the field, the time, air temperature, and other weather data were immediately recorded and the precise activity of the herd noted. Air temperatures were taken as the pattern of activity of the herd changed. The final morning temperature in summer was recorded when the herd under observation discontinued feeding.

These advantages of the feeding-minutes technique became evident as the study progressed: (1) a wide range of vegetative types and terrains could be studied; (2) only one man was needed to gather data and little equipment was required; (3) the qualitative data were relatively precise in showing what the animal ate; (4) the quantitative data, though subject to some error because of varying rates at which different plants were consumed, were sufficiently accurate to furnish reliable information on the relative amounts of food items consumed.

The technique had several limitations which were encountered in the study: (1) The amount of food consumed during 1 min. of feeding time on woody items such as mesquite beans, palo verde beans, and catclaw beans was far less than the amount consumed in the same time spent on a succulent such as pricklypear fruits or century plants. (2) Because it was occasionally impossible to see which of several plants was being consumed when the view was obstructed, it was sometimes necessary to estimate the amount of feeding sign on plants that had been clipped or gnawed off. (3) Peccaries do a great deal of rooting and it was often difficult to determine at what moment they came in contact with a food item. (4) More minutes were accumulated on readily visible plants such as cacti and century plants than on small forbs and tubers which were often taken when the animal's head was obscured by grasses, other plants, or rocks.

The contents of 40 peccary stomachs were also analyzed to determine foods eaten. Three were collected in December 1955; 9 during the February 1958 hunt; 1 each in March, April, and October 1958; and 12 during the February 1959 hunt. Twenty-eight of the samples were taken in

the palo verde–bursage–cacti vegetative type in the vicinity of Tucson; 12 came from the higher desert–grassland and oak–grassland types.

The samples were washed in tap water when first collected to remove the digestive juices and finely masticated particles. After washing, the samples were spread out on newspaper to dry; they were stored dry and later separated. The volume in cubic centimeters was determined by water displacement and the frequency of occurrence of each item was noted.

A third method of study was the examination of droppings. Peccaries regularly defecate in a number of small concentrated areas over their home range. These areas, from 1 to 20 sq. yd. in size, are known as scat stations. This behavior of the peccary is unique among big game mammals.

In the Tucson Mountain Park study area 42 scat stations were located. These stations were large enough to be considered permanent for the duration of the study. Of the 42 stations, 22 were located on saddles or ridges, 15 were located on hillsides, and 5 were along washes. Droppings were collected at the stations at 2-week intervals when possible. Each station was cleared of old droppings after each collection to insure a fresh sample for the following collection.

I analyzed 2,116 droppings, and for each food item estimated its percentage by volume and determined its frequency of occurrence.

STUDY AREAS

Tucson Mountain Park is located in the Tucson Mountains about 15 miles west of Tucson, Arizona. The study area was in the vicinity of Wasson's Peak, which rises to an elevation of 4,677 ft. and is flanked by lower peaks. The lower regions to the east and west of the main ridge are at about 3,000 ft. elevation. The lower elevations are characterized by long outwash detrital slopes with broad sandy washes crossing on the flats.

Nichol (1952) classified the vegetation in this area as the palo verde–bursage–cacti desert type. The area includes the following characteristic plant species: saguaro (*Carnegiea gigantea*), Engelmann's pricklypear (*Opuntia engelmannii*), drooping-spined pancake pear (*O. chlorotica*), jumping cholla (*O. fulgida*), staghorn cholla (*O. versicolor*), barrel cactus (*Ferocactus wislizeni*), bursage (*Franseria deltoidea*), desert hackberry (*Celtis pallida*), jojoba (*Simmondsia chinensis*), catclaw acacia (*Acacia greggii*), white-thorn (*A. constricta*), palo verde (*Cercidium microphyllum*), mesquite (*Prosopis juliflora*), ironwood (*Olneya tesota*), ocotillo (*Fouquieria splendens*), and brittle bush (*Encelia farinosa*).

Grasses are scarce over most of this study area. Those present included six-weeks grama (*Bouteloua barbata*), curly-mesquite (*Hilaria belangeri*), and tobosa (*H. mutica*).

The Santa Rita Experimental Range and foothills are located about 35 miles south of Tucson. This study area included the 50,000-a. Santa Rita Experimental Range and the foothills on the western slopes of the Santa Rita Mountains.

The vegetation type of this area is classified as desert–grassland or mesquite–grass savanna and is divided into subtypes (United States Forest Service, 1952).

The lower or "semi-desert" subtype varies in elevation from 2,900 to 3,500 ft. The dominant species are shrubs. Dense growth occurs only along the banks of the broad washes. The vegetation is characterized by Engelmann's pricklypear, Santa Rita cactus (*Opuntia santa-rita*), jumping cholla, burrowweed (*Aplopappus tenuisectus*), mesquite, ocotillo, desert hackberry, barrel cactus, velvet-pod mimosa (*Mimosa dysocarpa*), and catclaw acacia. Some important annuals are Arizona poppy (*Kallstroemia grandiflora*), filaree, lupines, and California poppy. Important perennials are wild gourds (*Cucurbita foetidissima*), and (*C. digitata*).

The "foothill" subtype above 4,000 ft. is composed essentially of mixed grama grasses (*Bouteloua* spp.), but includes areas where Emory oak (*Quercus emoryi*) and Arizona white oak (*Q. arizonica*) are dominant. Some other plants representative of the area are alligator-bark juniper (*Juniperus deppeana*), century plant (*Agave palmeri*), sotol (*Dasylirion wheeleri*), manzanita (*Arctostaphylos pungens*), and false-mesquite (*Calliandra eriophylla*).

The Canelo Hills are located about 60 mi. south of Tucson in a region between the south end of the Santa Rita Mountains and the west side of the Huachuca Mountains. The vegetation is oak–grassland. The elevation is about 6,000 ft. Plants characteristic of the area are Emory oak, Arizona white oak, silverleaf oak (*Quercus hypoleucoides*), Mexican blue oak (*Q. oblongifolia*), skunk-bush (*Rhus trilobata*), Mearn's sumac (*R. choriophylla*), silktassel (*Garrya wrightii*), birch-leaf mountain-mahogany (*Cerocarpus betuloides*), alligator-bark juniper, Mexican pinyon (*Pinus cembroides*), century plant, sotol, and numerous plants bearing small tubers, bulbs, and rhizomes.

The climate of the study areas is characterized by mild winters and warm to hot summers. There are two major seasons of precipitation, one during the winter months of December, January, and February; and the other during July and August.

Average annual precipitation at the Canelo Hills Ranger Station from 1910 through 1953 was 18.7 in.; at the Santa Rita Experimental Range from 1916 through 1953, 15.4 in.; and in the Tucson Mountains, 9.84 in. between 1943 and 1953 (Smith, 1956).

For the three areas the mean maximum temperatures for 10 or more years ranged from 74.2° F. in the Canelo Hills area to 82.7°F. in the Tuscon Mountain Park area. Mean minimum temperatures ranged from 56.4°F. in the Canelo Hills area to 69.4°F. in the Tucson Mountain Park area (Smith, 1956).

RESULTS

Field observations of feeding peccaries were made in each of the three previously described study areas. Feeding time in each area was totaled for each quarter beginning with July 1957. This procedure was used because it was found that the months of July, August, and September and the following months in groups of three represented distinct periods of food availability and adequately indicated seasonal trends in food habits.

Summaries of foods taken each season during the period from the summer of 1957 to the early spring of 1959 are recorded in Tables 1, 2, and 3. Each food plant was assigned an availability rating based on its relative abundance on the range. A rating of 1 indicates the species was easily accessible to peccaries, 2 indicates the food item was available in quantity but in restricted areas, and 3 indicates a scarcity of the plant on the range.

No feeding-minutes were recorded from January through March 1958 in the Santa Rita Experimental Range study area and during April through June 1958 in the Canelo Hills study area. However, peccary use of food plants in the area was noted. A list of plant species showing feeding sign and the number of times use was noted appear in Table 4.

In the 28 stomach samples collected from the palo verde–bursage–cacti desert, 21,987 cc. of material were examined. Prickly-pear made up 95 percent of the total contents by volume; forbs, 2 percent; unidentified leaves and stems, 1 percent; grass, 0.9 percent; and fishhook cactus (*Mammillaria microcarpa*) spines, 0.1 percent.

Stomach samples taken in the desert–grassland and oak–grassland types contained 11,028 cc. of material. Century plants (tissue and fiber) represented 96 percent of the total contents by volume; tubers, 3 percent; cholla seeds, 0.5 percent; pricklypear seeds, 0.5 percent.

No seasonal variations in diet could be determined because the data were taken

TABLE 1.—FOODS TAKEN AND OBSERVED FEEDING TIME ON EACH IN THE TUCSON MOUNTAIN PARK STUDY AREA

Plant Species	Plant Part Eaten	Total Minutes Spent Consuming Foods			
		Jul.–Sept.	Oct.–Dec.	Jan.–Mar.	Apr.–Jun.
Opuntia engelmannii	fruits	(1)[1] 452			(1)[1] 62
Opuntia engelmannii	pads		(1)[1] 369	(1) 124	
Carnegiea gigantea	fruits	(1) 253			(3) 13
Prosopis juliflora	beans	(2) 90			(2) 4
Cercidium microphyllum	beans	(1) 84			(2) 5
Simmondsia chinensis	fruits	(2) 38			(2) 8
Acacia greggii	beans	(3) 28			(3) 2
Ferocactus wislizeni	fruits		(2) 149	(2) 21	
Celtis pallida	berries	(2) 4	(2) 46		
Calliandra eriophylla	beans	(3) 3			
Allionia incarnata	foliage	(1) 7			
Mammillaria microcarpa	all	(3) 4			
Kallstroemia grandiflora	foliage	(2) 2			
Eschscholtzia mexicana	foliage			(2) 9	
Calycoseris wrightii	foliage			(3) 5	
Amsinckia intermedia	foliage			(2) 3	
Total		965	564	162	94

[1] Abundance rating.

TABLE 2.—FOODS TAKEN AND OBSERVED FEEDING TIME ON EACH IN THE SANTA RITA EXPERIMENTAL RANGE AND FOOTHILLS AREA

Plant Species	Plant Part Eaten	Total Minutes Spent Consuming Foods			
		Jul.–Sept.	Oct.–Dec.	Jan.–Mar.	Apr.–Jun.
Opuntia engelmannii	fruits	(1)[1] 442			(2)[1] 35
Opuntia engelmannii	pads		(1)[1] 175		
Prosopis juliflora	beans	(1) 173			
Quercus arizonica	acorns		(2) 116		
Quercus hypoleucoides	acorns		(2) 20		
Agave palmeri	base	(2) 143	(2) 76		(2) 29
Mammillaria microcarpa	all	(3) 70	(3) 16		
Celtis pallida	berries	(2) 57			
Acacia greggii	beans	(2) 51			
Ferocactus wislizeni	fruits	(2) 41			
Chenopodium album	foliage	(2) 26			
Hymenothrix wislizeni	foliage	(2) 25			
Cercidium microphyllum	beans	(3) 21			
Cucurbita foetidissima	tuber	(3) 18			
Cucurbita digitata	tuber	(3) 18			
Kallstroemia grandiflora	foliage	(2) 11			
Amaranthus sp.	foliage	(2) 5			
Tidestromia lanuginosa	foliage	(2) 3			
Evolvulus arizonicus	foliage	(2) 3			
Allionia incarnata	foliage	(1) 3			
Total		1,110	403		64

[1] Abundance rating.

principally from hunter-kills in February. Relative use of different food plants was difficult to determine because of the probable great variation in length of digestion times necessary for different plants. Pricklypear and century plant tissues contain many fibers which are slower to digest than forbs, fruits, berries, tubers, or bulbs.

Analyses of droppings (Table 5) proved helpful in showing seasonal use of fruits which contained indigestible seeds, as well as periods of use of pricklypears and century plants.

Feeding patterns

Peccaries in the Tucson Mountain Park and the Santa Rita study areas showed seasonal patterns of feeding activity. In summer, feeding took place only in morning and evening hours. During the interim the herds returned to caves or bedded down in well-shaded canyons, under rock outcrops, or in dense shrubs. When temperatures dropped and the days became shorter in autumn, morning and evening feeding periods increased in length. The animals usually bedded down in canyons or in washes in dense palo verde, hackberry, or mesquite.

During the winter months, feeding activity generally lasted throughout the day, but rest periods were of shorter duration. On extremely cold days in the Tucson Mountains study area, herds sought the shelter of caves or tunnels, presumably to avoid cold and wind.

When the weather again became warm in spring, feeding periods became shorter. Movements were similar to those of summer.

In a typical pattern of activity, a herd moved out of its resting place at daybreak or shortly afterwards and traveled to a nearby feeding ground. When herds moved to feeding areas, from feeding areas to resting sites, or to water, they generally traveled in single file along game trails, fanning out when the trail was momentarily lost or when a wash or canyon was crossed. When moving, animals were often close together, although the herd column was occasionally broken into several segments.

Herds fed in loosely knit units that varied greatly in compactness during feeding ac-

TABLE 3.—FOODS TAKEN AND OBSERVED FEEDING TIME ON EACH IN THE CANELO HILLS STUDY AREA

Plant Species	Plant Part Eaten	Total Minutes Spent Consuming Foods			
		Jul.–Sept.	Oct.–Dec.	Jan.–Mar.	Apr.–Jun.
Ipomoea muricata	tubers	(1)[1] 359	(1)[1] 61	(1)[1] 31	
Agave palmeri	base	(2) 258	(1) 157	(2) 30	
Arctostaphylos pungens	berries	(2) 187			
Cyperus sp.	rhizomes	(3) 44			
Quercus arizonica	acorns		(2) 27	(2) 44	
Quercus hypoleucoides	acorns		(3) 9		
Dasylirion wheeleri	base	(3) 16			
Rhus choriophylla	berries	(3) 13			
Opuntia engelmannii	pads	(3) 9			
Phaseolus acutifolius	tubers		(3) 5		
Commelina dianthifolia	tubers		(3) 5		
Rhus trilobata	berries	(2) 4			
Quercus emoryi	acorns	(2) 2			
Juniperus deppeana	berries	(3) 1			
Pinus cembroides	nuts	(3) 1			
Muhlenbergia emersleyi	foliage	(2) 1			
Trichachne californica	foliage	(3) 1			
Total		896	264	105	
ANIMAL SPECIES					
Insecta					
Brachystola magna		12			

[1] Abundance rating.

tivity. When a particularly attractive cactus plant or tuber bed was located, the herd often assembled in a group around the plant or bed and fed close together. Feeding herds generally moved in the same direction; if direction was altered, the herd broke up and the animals scattered unless they were in a canyon. In this case, all animals generally moved up the sides of the canyon if they were not too steep. There seemed to be no lead animal to direct movements of the herd when danger arose. Feeding generally took place while the animals were heading into the wind.

When the morning feeding period ceased at mid- or late morning, the herd congregated in the shade of dense brush cover or in a canyon or cave and passed the hot hours of the day loafing, dusting, and scratching.

The extent to which peccaries feed at night was not determined in this study. However, observations of herds on moonlight nights showed that peccaries do feed during night hours, principally in the hot summer months. Night movements of peccary herds to water tanks were observed by Elder (1956).

Peccaries fed in a wide variety of terrains. Of the 99 observations made during the study, 43 were in wash bottoms, 28 on flats, 20 on hillsides, and 8 in canyons. Feeding herds avoided extremely rocky areas, especially talus slopes and craggy areas where footing was insecure and hazardous.

From late April until mid-October, the morning feeding activity terminated when the air temperature rose to about 90°F. Feeding was resumed in the evening when the temperature declined to approximately

TABLE 4.—INSTANCES OF USE OF PLANTS IN SANTA RITA EXPERIMENTAL RANGE, JANUARY–MARCH 1958; CANELO HILLS, APRIL–JUNE 1958

Plant Species	Number of Times Plant Used	
	Santa Rita	Canelo Hills
Opuntia engelmannii	193	23
Agave palmeri	120	31
Ipomoea muricata		614
Opuntia fulgida	13	
Opuntia versicolor	14	
Mammillaria microcarpa	9	
Dasylirion wheeleri		3

TABLE 5.—CONTENTS OF PECCARY DROPPINGS COLLECTED FROM TUCSON MOUNTAIN PARK STUDY AREA

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
No. of Samples	42	60	54	73	104	153	518	687	103	118	122	82
Items	Estimated Percent by Volume											
Pricklypear fiber	92	82	82	80	92	55		5	40	85	90	95
Pricklypear seeds						2	8	83	40	5		
Barrel cactus seeds	1	1								1	1	1
Fishhook cactus spines			3	2		1		1				
Forbs, unidentified		14	10	10								
Saguaro seeds						30	85					
Plant debris	7	3	5	8	8	12	7	11	20	9	9	4

90°F., either ceasing at sunset or continuing after dark.

Winter feeding activity was more uniform because of an absence of extremely high temperatures which peccaries attempted to avoid by seeking cooler areas.

During periods of high winds, heavy rains, or electrical storms, peccaries did not feed; they sought the densest vegetative cover available. If caves or tunnels were available, they were frequently used. During severe weather conditions, herd movements became erratic and their daily activity pattern was disrupted. Feeding was confined largely to periods when breaks in the weather occurred. Jennings and Harris (1953) also reported that peccaries did not feed during severe weather.

Competition and effect on vegetation

Some people believe that competition exists between peccaries and cattle. Throughout this study an effort was made to determine the extent and seriousness of the competition. Two methods were used: (1) a comparison of areas on the range most inhabited by cattle with areas most inhabited by peccaries, and (2) a comparison of the foods of cattle and peccaries on the study areas. Significant competition probably does not exist except in rare instances where the supply of important food plants is low and peccary numbers are high.

Peccaries compete with other wildlife species for many of the important foods in their diet. Mast as well as fruits are also used by many small mammals and birds. Deer (*Dama hemionus*) consume large quantities of green succulent forbs. Barrel cactus fruits are also consumed by deer and jackrabbits (*Lepus californicus* and *L. alleni*). Deer, coyotes (*Canis latrans*), and foxes (*Urocyon cinereoargenteus*) also eat pricklypear fruits. Birds consume the core of saguaro fruits on the plant and thus decrease their value to peccaries. There is little competition for tubers and bulbs or cactus pads.

In the oak–grassland type, coatimundis (*Nasua narica*) compete with peccaries for pinyon nuts, acorns, and juniper berries.

The effect of competition on the total food supply of the peccary is difficult to measure; however, adverse effects on food supply due to competition are probably rare and occur only during periods when the total available food supply is greatly reduced by drought.

Thirty percent of those questioned by Knipe (1957) who had peccaries on their property said they believed the animals were causing damage to the range. I found no evidence to indicate that peccaries were detrimental to range vegetation to such a degree that landowners should be concerned, except in rare instances where peccary concentrations destroyed seedlings and promoted erosion by removing vegetation on steep slopes.

DISCUSSION

Feeding-minutes data are not believed to be necessarily indicative of the palatability of food items. Instead, the data probably show the relative importance of various food plants on a seasonal basis.

Pricklypear was the most important food item in the two lower elevation study areas.

Fifty-six percent of the feeding-minutes in the palo verde–bursage–cacti type were spent on either pricklypear pads or pricklypear fruits. In the desert–grassland, 41 percent of the observed feeding time was devoted to pricklypear. Where other foods were available, the use of pricklypear decreased. The abundance of pricklypear throughout the lower elevations of peccary range make it a vital part of the requirements of good year-round peccary habitat.

Use was noted on fishhook, hedgehog (*Echinocereus* spp.), cholla, and barrel cacti. Fishhook and hedgehog cacti were highly relished and, when located, were almost invariably consumed. The fleshy tissues covering the trunk and joints of cholla were occasionally eaten by peccaries when other foods were scarce. The shells of three barrel cacti were found after recently having been hollowed out by peccaries.

Cacti fruits made up the bulk of the peccaries' diet during the summer in the Tucson Mountains and Santa Rita study areas. In the palo verde–bursage–cacti type, the period of availability of fleshy cacti fruits started with the drop of saguaro fruits in late June. Ripe pricklypear fruits became abundantly available in mid-July. Saguaro fruit was not available after about the last week in July. Pricklypear fruits were used by peccaries until late September or early October. Occasionally a few fruits remained on the plants through the winter and these were utilized by peccaries even though they were tough and lacked succulence. Barrel cactus fruits formed in early fall and were available until late winter when the crop was depleted by peccaries, deer, and jackrabbits.

From observations of peccaries feeding in the field, observations of penned animals, and examination of stomach contents and droppings, it was evident that animal matter was of minor importance in the diet of the peccary in southern Arizona. Of 4,639 feeding-minutes recorded during the study, peccaries spent only 12 minutes feeding on animal matter (Table 3).

Within the oak zones of the Canelo Hills and Santa Rita study areas, four species of oaks furnished annual mast crops to peccaries and other wildlife species. These crops were variable and impossible to predict accurately. During 1957 and 1958, acorn production was moderately heavy in the oak regions of the Santa Rita Experimental Range and foothills study area. From October through December peccaries spent 34 percent of the recorded feeding time eating acorns. Arizona white oak was the greatest producer of mast in the area. During the same period, acorn production in the Canelo Hills study area was low and only 14 percent of the total feeding time was devoted to acorns.

Peccaries spent considerable time rooting for small underground plant parts. Seven species of plants bearing thickened underground portions were used by peccaries in the study areas. *Ipomoea muricata*, a perennial tuber-bearing morning-glory, was extensively taken by peccaries in the Canelo Hills study area; 36 percent of the observed total feeding time in the area was spent on this plant. According to the feeding-minutes data, it was one of the three major food plants in the type.

Other species of minor importance included the tepary bean (*Phaseolus acutifolius*), dayflower (*Commelina dianthifolia*), covena (*Dichelostemma pulchellum*), *Cirsium* sp., and two species of wild gourds (*Cucurbita foetidissima* and *C. digitata*).

In the foothill subtype of the Santa Rita study area a thistle (*Cirsium* sp.) was found growing in scattered patches on hills and canyon sides. This biennial produced a tapering fleshy root, which peccaries relished, but they rejected the prickly rosette. Patches of earth as large as 10 a. in size were examined that were completely denuded of this plant. The plant was used most extensively in October, November, and December, and supplemented century plants and acorns.

Peccaries have the ability to locate edible underground items (roots, tubers, bulbs, rhizomes) by smell. Presence of the aboveground vegetative portion was not necessary for location of underground items.

Large plots of diggings were found in winter where the aboveground portion of the plants had withered and blown away.

In the study areas a number of woody shrubs and trees produced mast crops which peccaries relished. They utilized acorns, fruits, berries, and beans extensively during summer and fall.

In the oak–grassland and in the foothill subtype of the desert–grassland study areas, manzanita occurred abundantly on many hillsides and in scattered patches on ridges and stream banks. From mid-July to late August during 1958, this plant produced a crop of small, reddish-orange berries. The crop was not always available at the same time each year, and occasionally it did not occur at all. It was therefore important only locally when conditions were favorable for an abundant mast crop. Peccaries spent 20 percent of the total feeding-minutes eating manzanita berries during the time of their availability.

During active feeding periods much time was devoted to what appeared to be random rootings. This activity usually occurred in conjunction with feeding on fallen fruits, nuts, and beans, or on pricklypear, century plant, or forbs. Observations indicated that the animals devoted approximately one-eighth of the feeding time to rooting activity. It was extremely difficult to observe the specific items peccaries picked up during rooting, but from results of stomach analyses and from a few field observations made from especially advantageous positions it was possible to compile a list of some items taken. Included were grasshoppers, crickets, beetles, insect larvae, carrion (small rodents, birds, and reptiles), acorns, pinyon nuts, juniper berries, small tubers, bulbs, beans, berries, mushrooms, shoots of young forbs and grasses.

Use of acorns was at a peak during the late fall months. Acorns, along with century plants and tubers, made up the important food items in the oak zones of the two higher elevation study areas.

Catclaw, palo verde, and mesquite were present in the desert washes and on hillsides in the Tucson Mountains and Santa Rita study areas. These plants produced beans which peccaries relished. The crops were not dependable, but occasionally quantities were produced which were used through the summer into early fall.

Mesquite beans made up 10 percent of the recorded diet of peccaries in the Tucson Mountains study area from July through September, according to the feeding-minutes data. Palo verde beans contributed 9 percent of the total; catclaw beans, 3 percent. Jojoba is relatively abundant in the Tucson Mountains area and produces an annual crop of nutritious fruits. Four percent of the total observed feeding time during July, August, and September was devoted to these fruits.

During the same period in the Santa Rita Experimental Range study area, 16 percent of the total feeding time was spent on mesquite beans; catclaw beans received 5 percent, and the relatively scarce palo verde beans, only 2 percent.

In the oak–grassland and the foothill subtype of the Santa Rita study area the century plant occurs in scattered patches along ridges, hillsides, and canyons. In these areas the plant serves as a major food item throughout the year and constitutes the bulk of the peccaries' diet.

In the oak–grassland area 35 percent of the total observed feeding time was devoted to century plants; in the desert–grassland area, 16 percent.

From observations of feeding peccary herds and from examination of plots where peccaries had recently fed on young herbaceous growth, it became evident that forbs were heavily utilized. When winter annuals began to grow in February, the only food plants available in sufficient amounts to furnish needed bulk in the diet in the palo verde–bursage–cacti and lower desert–grassland types were pricklypear, and, in the upper elevations of the desert grassland study area, century plant. At this time young forbs were consumed in preference to cacti.

Because of the relatively short period of availability of forbs, they were not important as a staple food item in the peccaries'

diet but formed an important supplement when fruits, berries, and beans were absent. The use of forbs decreased gradually through March and April. Little feeding took place on the plants after they had matured. The appearance of new growth in July following the summer rains brought about another period of use, which continued until September or early October.

Feeding-minutes data indicated that grasses made up an insignificant portion of the peccaries' diet. During the course of this study peccaries were noted to eat grass on only two occasions.

In peccary range where succulents were available throughout the year in the form of cacti, cactus fruits, or forbs, peccaries did not ed free water unless unusually long periods of drought caused the succulents to become dehydrated. Under drought conditions, as observed in the Tucson Mountain Park, herds occasionally left the home range and sought water from tanks and holes as far as 2 mi. from the ordinary limit of the herd range. In a study conducted at the University of Arizona, penned peccaries experienced no apparent ill effects after being on a waterless diet of pricklypear pads only for a period of 2 weeks. Pricklypear plants were found to contain from 78 to 88 percent water, the fruits, from 65 to 75 percent.

SUMMARY

The foods eaten by peccaries in southern Arizona were determined by application of the feeding-minutes technique, and by analyses of stomach contents and droppings.

Pricklypear pads and fruits were the major food items in the palo verde–bursage–cacti vegetative type. Pricklypear and century plants were the most important foods in the desert–grassland vegetative type. Century plants and tubers made up the bulk of the peccaries' diet in the oak–grassland vegetative type. Cactus fruits, beans, berries, and annual forbs provided valuable seasonal supplements in the peccaries' diet.

Seasonal feeding-activity patterns were noted. Late spring, summer, and early fall were characterized by a midday rest period. Winter feeding activity generally lasted throughout the day. Temperatures of approximately 90°F. caused peccaries to terminate feeding activity and seek resting places.

Significant competition between cattle and peccaries probably did not exist except in rare cases where the supply of important food plants was low and peccary numbers were high.

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CONSUMPTION OF SOME FOOD ITEMS BY PEN-REARED BOBWHITES

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Reports on the food habits of the bobwhite (*Colinus virginianus* L.) are available from representative areas throughout its range. These indicate that the diet of the bobwhite consists largely of plant seeds and that the percentages of the different kinds of seeds vary in relation to availability, digestibility, nutritive value, and perhaps other factors. Heredity and environmental conditioning may also determine the food items that are selected by a bobwhite. This study was undertaken to evaluate quantitatively the relationship between availability and consumption of various seeds in the diet of the bobwhite and to gain more insight into the problem of food selection.

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Procedure

A cafeteria method of feeding in which equal volumes of 10 food items were fed for 1-week periods was devised. Adult, hatchery-reared bobwhites, housed in McCarthy pens (Hart and Mitchell, 1947), were subjected to 12 such trials from January 17, 1954, to June 10, 1954.

Food items in each trial were made available to two of six groups of birds, each containing three cock-hen pairs of quail. An equal volume of seeds was presented to each of two experimental groups. During the first five feeding trials, feed pans were checked every 24 hours. In the remaining seven, pans were checked at 12-hour intervals. At the conclusion of a 12- or 24-hour period, feed pans were washed and rinsed in an effort to eliminate olfactory discrimination (Frings and Boyd, 1952).

A single group of three cock-hen pairs of quail was maintained on a diet of cracked corn during each feeding trial. This was done in order to compare weights of birds on experimental diets with weights of quail fed a highly nutritive and familiar food. The volume of cracked corn presented to the control group was equal to the volume of seeds presented to each of the experimental groups.

When quail were not on experimental diets, they were maintained on a diet of scratch grain consisting mainly of cracked corn and wheat. A commercial quail ration was provided in conjunction with scratch grain, but the birds did not consume an appreciable amount of it as long as scratch grain was present. Water was available to the birds at all times. Quail in the experimental and control groups were weighed immediately prior to the beginning of each feeding experiment and again 12 hours after the final feeding.

Nine of the 12 trials were designed to compare consumption of food items in a given ecological situation frequented by quail. In these trials, the diet was composed of 10 kinds of seeds found to be readily available to quail within the following land-use divisions in southern Illinois (Bookhout, 1954), as shown in Tables 2 and 3: Permanent Cover, Hayfield, Rotation Pasture, Soybean, Lespedeza, Idle Plowland, Small Grain and Corn. Seeds from the Corn land-use division were used in two feeding trials; the Corn I trial did not contain corn, while in the Corn II trial corn was substituted for bluegrass. Two trials (Crop Analysis I and II) were con-

ducted to compare the consumption of different food items in relation to their occurrence by percent volume in crops of wild quail collected during the hunting seasons in southern Illinois in 1950 and 1951. Seeds occupying approximately every fifth position in a list of foods by percent of volume (Larimer, 1960) were used in the trials. Seeds presented in the Crop Analysis I trial thus occupied higher positions on the food list than those presented in the Crop Analysis II trial. A final feeding trial (Miscellaneous) was made using miscellaneous seeds not presented in other trials or presented only once previously. Trials used, order, and dates of feeding are shown in Table 1.

The native seeds used in this study were collected near Carbondale, Illinois, during the summer and fall of 1952 and 1953; the cultivated seeds were purchased at local feed stores. The volume of all seeds was determined by the water displacement method.

Seeds used in the feeding trials were: fescue grass, *Festuca* L. sp.; Kentucky bluegrass, *Poa pratensis* L.; wheat, *Triticum aestivum* L.; barley, *Hordeum vulgare* L.; rye, *Secale cereale* L.; oat, *Avena sativa* L.; timothy, *Phleum pratense* L.; smooth crabgrass, *Digitaria ischaemum* Schrab. Muhl.; roundseed, *Paspalum circulare* Nash.; fall panicum, *Panicum dichotomiflorum* Michx.; barnyard grass, *Echinochloa crusgalli* L. Beauv.; yellow foxtail, *Seteria lutescens* Wegil F. T. Hubb.; broomsedge, *Andropogon virginicus* L.; corn, *Zea mays* L.; greenbrier, *Smilax* L. sp.; black oak, *Quercus velutina* Lam.; osage-orange, *Maclura pomifera* Raf. Schneid.; curly dock, *Rumex crispus* L.; water-pepper, *Polygonum hydropiper* L.; Pennsylvania smartweed, *Polygonum pennsylvanicum* L.; false buckwheat, *Polygonum scandens* L.; lamb's quarter, *Chenopodium album* L.; rough pigweed, *Amaranthus retroflexus* L.; white avens, *Geum canadense* Jacq.; rose, *Rosa* sp.; alsike clover, *Trifolium hybridum* L.; crimson clover, *Trifolium incarnatum* L.; red clover, *Trifolium pratense* L.; tick-clover, *Desmodium* Desv. sp.; Korean lespedeza, *Lespedeza stipulacea* Maxim.; shrub lespedeza, *Lespedeza bicolor*; soybean, *Glycine max* L. Merr.; smooth sumac, *Rhus glabra* L.; poison ivy, *Rhus radicans* L.; grape, *Vitis* sp.; prickly sida, *Sida spinosa* L.; rough buttonweed, *Diodia teres* Walt.; common ragweed, *Ambrosia artemisiifolia* L.; giant ragweed, *Ambrosia trifida* L.; lanceleaf ragweed, *Ambrosia bidentata* Michx.; and beggarticks, *Bidens* L. sp. Nomenclature is after Jones and Fuller (1955) or Kelsey and Dayton (1942).

TABLE 1.—PERCENTAGE CHANGE IN AVERAGE WEIGHTS DURING FEEDING TRIALS OF EXPERIMENTAL AND CONTROL GROUPS[1] OF QUAIL

Feeding Trial	Dates of Feedings 1954	Percentage Change in Weight	
		Experimental Birds	Control Birds
Permanent Cover	Jan. 17–24	–21.7	–1.5
Crop Analysis I	Feb. 1– 8	– 8.0	–6.2
Hayfield	Feb. 10–17	–10.3	–3.5
Corn I	Feb. 28–Mar. 7	– 4.9	–3.5
Crop Analysis II	Mar. 24–31	– 4.7	–2.5
Rotation Pasture	Apr. 2– 9	– 7.8	–4.3
Soybean	Apr. 14–21	– 2.4	–0.9
Lespedeza	Apr. 25–May 2	– 2.8	–2.4
Idle Plowland	May 3–10	– 3.8	–2.4
Small Grain	May 18–25	– 1.9	–1.4
Miscellaneous	May 18–25	– 0.9	–1.4
Corn II	June 3–10	– 1.0	+2.2

[1] The control groups were maintained on cracked corn during all experimental feeding trials.

FINDINGS AND DISCUSSION

Average consumption of individual seeds and average weight of experimental birds varied with the different feeding trials (Tables 1, 2, and 3). Total average consumption of seeds ranged from a maximum of 388.8 cc. in the Crop Analysis I trial to a minimum of 68.2 cc. in the Permanent Cover trial, indicating that penned quail most readily accepted the same kinds of seeds that were found in greatest quantity in crops of wild quail.

Weight loss of the experimental birds ranged from 21.7 percent in the Permanent Cover trial to 0.9 percent in the Miscellaneous feeding trial (Table 1). The percent change in average weights of control birds maintained on corn and of experimental groups was most similar in the Lespedeza feeding trial and was least similar in the Permanent Cover feeding trial.

Factors Affecting Consumption

Indication of preferences.—In order to determine whether quail had preferences for certain seeds in the various feeding trials, a series of *t* tests was performed by comparing the amount of each type of seed consumed with the pooled amounts of seeds consumed within the same trial. From such tests, 108 numbers were tabulated. A table

TABLE 2.—SEEDS USED IN THE CAFETERIA FEEDINGS, PERCENT CONSUMED, AND RANK (1 TO 10) BASED ON PERCENTAGE

	PERCENT OF SEEDS CONSUMED PER FEEDING TRIAL					
	Permanent Cover[1]	Crop Analysis I[2]	Hayfield[3]	Corn I[3]	Crop Analysis II[4]	Rotation Pasture[5]
FOOD ITEM						
Fescue grass				35.7 (8)		60.0 (5)
Bluegrass				14.6 (10)		
Wheat		96.9 (1)				
Barley			97.5 (1)			
Rye					99.1 (1)	
Oat		93.3 (5)				
Timothy					65.7 (7)	
Smooth crabgrass	26.7 (9)			67.0 (2)		50.1 (8)
Roundseed		91.2 (6)	82.3 (7)			69.9 (2)
Fall panicum		90.4 (7)	73.7 (9)	64.4 (4)		57.6 (7)
Barnyard grass					17.9 (10)	
Yellow foxtail	43.1 (8)		94.9 (2)	67.1 (1)		
Broom-sedge						2.5 (10)
Corn		96.6 (2)				
Curly dock			84.0 (6)	51.5 (6)	61.2 (8)	
Pa. smartweed	50.4 (7)			38.2 (7)		
Lamb's quarter				35.7 (9)	20.4 (9)	
Pigweed	17.6 (10)					17.6 (9)
White avens		89.4 (8)				
Rose					87.9 (6)	
Alsike clover			77.7 (8)			
Crimson clover			86.2 (4)		95.7 (2)	
Red clover			85.4 (5)			74.0 (1)
Tick-clover	76.9 (4)					
Korean lespedeza			72.9 (10)			65.3 (4)
Shrub lespedeza					90.3 (5)	
Smooth sumac	97.0 (1)					
Poison ivy		96.3 (3)				
Grape					94.3 (3)	
Prickly sida				56.1 (5)	94.2 (4)	
Rough buttonweed	82.1 (3)	56.0 (9)		66.3 (8)		59.2 (6)
Common ragweed	74.4 (5)		90.3 (3)			66.0 (3)
Giant ragweed	92.7 (2)					
Lanceleaf ragweed		96.3 (4)				
Beggar-ticks	59.4 (6)	27.2 (10)				
Average total consumed (cc.)	68.2	388.8	118.2	69.5	218.0	78.3

[1] Average total volume (cc.) presented 110.0.
[2] Average total volume (cc.) presented 470.0.
[3] Average total volume (cc.) presented 140.0.
[4] Average total volume (cc.) presented 300.0.
[5] Average total volume (cc.) presented 150.0.

of the *t*-distribution for one degree of freedom was used to determine how many of the numbers fell within each of the possible groups listed in Table 4. A chi-square test was performed by using the corresponding percentages of 108 as predicted values; the last five totals were grouped. A chi-square value of 449.629 with 9 d.f. was obtained, which was significant at the 0.001 level. This test indicated preferences for some seeds, but the degree of preference for specific food items could not be determined.

Volume of seed presented and size of individual seeds.—The volume of seeds presented during the feeding trials was found to have influenced the amount of seeds consumed by quail. The relationship was a direct one; the more seeds made available

TABLE 3.—SEEDS USED IN THE CAFETERIA FEEDINGS, PERCENT CONSUMED, AND RANK (1 TO 10) BASED ON PERCENTAGE

	PERCENT OF SEEDS CONSUMED PER FEEDING TRIAL					
	Soybean[1]	Lespedeza[1]	Idle Plowland[1]	Small Grain[1]	Miscellaneous[2]	Corn II[3]
FOOD ITEM						
Fescue grass						7.7 (10)
Bluegrass	10.7 (10)					
Barley		65.4 (8)				
Oat				93.1 (1)		
Timothy			62.2 (7)			
Smooth crabgrass	52.8 (6)	73.9 (6)	78.8 (4)	66.7 (8)		68.4 (4)
Roundseed		75.3 (3)	59.4 (8)	77.0 (5)		
Fall panicum	85.6 (2)	85.1 (1)	81.0 (3)	88.3 (2)		71.0 (2)
Barnyard grass			4.5 (10)			
Yellow foxtail	61.4 (5)	80.2 (2)				54.8 (5)
Corn						89.2 (1)
Greenbrier					70.8 (7)	
Black oak					92.1 (3)	
Osage-orange					93.6 (2)	
Curly dock	48.8 (7)	74.6 (5)		74.5 (6)		29.1 (8)
Water-pepper					92.1 (4)	
Pa. smartweed		25.2 (10)	33.8 (9)	63.1 (9)		21.5 (9)
False buckwheat					87.9 (6)	
Lamb's quarter				61.9 (10)		31.4 (7)
Rough pigweed	34.0 (9)			73.5 (7)		
White avens					60.1 (9)	
Rose					37.9 (10)	
Red clover	69.2 (4)					
Tick-clover					90.8 (5)	
Korean lespedeza		72.8 (7)	82.8 (2)	83.8 (4)		
Soybean	86.4 (1)					
Smooth sumac					96.2 (1)	
Grape					69.8 (8)	
Prickly sida						53.5 (6)
Rough buttonweed	43.2 (8)	61.5 (9)	71.4 (5)	84.4 (3)		70.7 (3)
Common ragweed	78.6 (3)		89.2 (1)			
Lanceleaf ragweed		75.2 (4)				
Beggar-ticks			70.4 (6)			
Average total consumed (cc.)	148.3	179.2	164.7	199.2	213.7	378.0

[1] Average total volume (cc.) presented 260.0.
[2] Average total volume (cc.) presented 270.0.
[3] Average total volume (cc.) presented 760.0.

to the experimental birds, the more they consumed. A correlation coefficient value of 0.911 (significant at the 0.01 level) was obtained by comparing the amount of seeds presented in each diet with the corresponding amount consumed (Fig. 1). However, there was no statistical correlation between the amount of seeds consumed during feeding trials by experimental and control birds and subsequent changes in weights.

The sizes of seeds that ranked first according to percent consumption in the 12 trials varied greatly. The smallest item by volume was smooth crabgrass (0.0005 cc.), and the largest item, whole corn (0.2000 cc.). The average size of the items that ranked first according to percent consumption in feeding trials was 0.0393 cc., which is slightly larger than the average volume of a giant ragweed seed (0.0365 cc.).

Social organization.—A "peck order" existed among quail maintained in the six compartments during the winter months, as was evidenced by the physical appearance and body weights of the birds. One cock in each group appeared to be in better con-

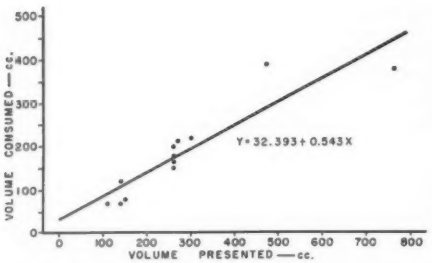

FIG. 1. Correlation showing the relationship of the volume of seeds presented to volume of seeds consumed.

dition than the other males and weighed more at the beginning and at the conclusion of an experiment. It was not known how the "peck order" affected consumption within a particular feeding trial because no direct observations were made on the feeding activities. This behavioral pattern changed with the advent of the breeding season at which time weights and appearances of cocks became uniform.

Vicious habits.—Cannibalism, coprophagy, and egg consumption, which are considered as vicious habits in penned gallinaceous birds (Schwarte, 1952), occurred at various times in this study, but were most common during the breeding season. Coprophagy was also observed in winter, particularly in the final feedings (about the 5th or 6th day) of feeding trials.

Coprophagy was not noticed as frequently among birds maintained on cracked corn as among experimental birds. This difference was believed to have been influenced by the fact that the experimental diets did not provide full nutritional needs of the birds as well as did cracked corn.

Effect of depletion of some items.—Efforts were made to prevent complete consumption of any food item during a feeding period (interval between the times the feeders were checked). It was, however, impossible to determine in advance the quantity of seeds needed to insure an adequate supply at all times.

In 33 of the 266 intervals (feeding periods) between the times food was supplied to experimental birds in feeding trials, one or more items were depleted. In general, items completely eaten in a feeding period were those that ranked high in the final analysis of a particular trial. Quail maintained on the control diet of cracked corn consumed the entire quantity regularly.

Depletion of a food item within a feeding period was accompanied almost invariably by a substantial increase in consumption of items that ranked next highest in the final analysis of a particular trial. If the entire quantity of one item was consumed in one feeding period and again later in the same trial, quantitive consumption of the remaining items was not always similar.

Nutritional values.—A critical evaluation of the nutritional value of individual food items was not within the scope of this study. The change in average weights of birds on the experimental diets, however, may be used as a criterion of nutritional values of the feeding trials. Protein requirements for quail in the breeding season and for non-reproductive mature birds in winter have been found to be different (Nestler, 1949).

According to Errington (1939), occur-

TABLE 4.—DISTRIBUTION OF 108 VALUES OF t[1]

Frequency of t	Distribution of 108 Values of t	Predicted X^2[3] Values
100–90	1	10.80
90–80	0	10.80
80–70	1	10.80
70–60	2	10.80
60–50	5	10.80
50–40	2	10.80
40–30	6	10.80
30–20	10	10.80
20–10	14	10.80
10– 5	20[2]	5.40
5– 2	21[2]	3.24
2– 1	15[2]	1.08
1– 0.1	10[2]	0.972
0.1– 0.0	1[2]	0.108

[1] The 108 values were tested by a chi-square analysis to determine if the quail showed preferences for some foods. The t values were calculated by comparing the amount of each type of seed consumed with the total amount of seeds consumed within each of the 12 feeding trials.

[2] Grouped for X^2 test.

[3] X^2 Value 449.629 with 9 d.f. (significant at 0.001 level).

rence of a very great variety of items recorded only as traces or in other small amounts in the crops of wild quail suggests that some seeds may have physiological significance far out of proportion to their dietary representation. Therefore, specific nutritional needs of the experimental birds could possibly have been satisfied by consuming small quantities of one or more items presented in these trials. Because of drastic weight losses among the birds, it was doubtful that the seeds comprising the diets used in the Permanent Cover, Hayfield, Crop Analysis I, and Rotation Pasture feeding trials were sufficient to satisfy the nutritional requirements of the experimental quail.

Reaction to and Acceptance of Certain Foods

Many workers have stated that bobwhites have the ability to recognize and eat acceptable food items. According to Davison (1949), quail will eat any good food the first time they encounter it. Errington (1939) states ". . . one may justifiably expect Bobwhites sooner or later to sample or to eat incidentally almost any objects of swallowable sizes occurring in their habitats." Based on a food preference study of penned bobwhites, Michael and Beckwith (1955) concluded that the birds did not require an introductory period to become accustomed to acceptable new foods.

The foods used in this study, when presented for the first time, were completely foreign to the birds except for those items that appeared in scratch grain. The birds accepted all foods to some degree in the course of the trials; none were completely avoided. Initial consumption of a seed during the trials often was not a reliable indication of its consumption at the end of the experiment.

Only a few items were rejected by the experimental group of quail during the first feeding periods of the feeding trials. Poison ivy, beggar-ticks, and lanceleaf ragweed were not accepted during the first feeding period of the Crop Analysis I trial. In the Rotation Pasture diet, broom-sedge was rejected during the first feeding period. Five different seeds, timothy, roundseed, barnyard grass, Pennsylvania smartweed, and rough buttonweed were avoided during the first feeding period in the Rotation Pasture trial. Roundseed and barnyard grass were also avoided during the second feeding period; but all items were sampled during succeeding feeding periods of the trial. Pennsylvania smartweed was not eaten in the first feeding period in the Small Grain feeding trial. It was, however, taken in ensuing feeding periods of this test.

Frequent inclusion of some seeds in the trials resulted in an increased consumption of these foods. Four feeding trials, Soybean, Lespedeza, Idle Plowland, and Small Grain, were conducted in sequence with the same groups of quail. The volume of seeds presented during the course of the tests was equal (Table 3). Ten food items occurred in two or more of these feeding trials. Seven of the seeds, yellow foxtail, curly dock, Pennsylvania smartweed, rough pigweed, Korean lespedeza, rough buttonweed, and common ragweed were consumed in increasing quantities. One food, fall panicum, was consumed in about equal quantities even though it appeared in all four feeding trials. Two foods, roundseed and smooth crabgrass, were not consumed in any consistent pattern during the course of the feeding trials.

Michael and Beckwith (1955) found that quail preferred grasses over legumes. Generally, in this study, the cereal crop seeds (wheat, corn, oat, barley, and rye) were consumed in greater quantities than those of agricultural legumes and native foods. This was true in the Hayfield feeding trial where barley outranked crimson clover, alsike clover, and red clover (Table 2). Rye was consumed in larger quantities than crimson clover when the two were presented in the Crop Analysis II feeding trial. In the Lespedeza feeding trial, however, barley ranked eighth, below four native grasses and Korean lespedeza. In the Hayfield feeding trial a native grass, yellow foxtail, was consumed in larger quantities than the agricultural legumes, crimson

clover, alsike clover, and red clover. Red clover, however, outranked smooth crabgrass, fall panicum, fescue, and roundseed in the Rotation Pasture feeding trial.

Nestler, *et al.* (1945) found corn, common ragweed, and shrub lespedeza to be preferred foods of penned quail. Corn was readily eaten during the two trials in which it was included in this study. Common ragweed was presented in 5 of the 12 trials and ranked first according to percent consumed in the Idle Plowland feeding trial. It was also readily accepted in the other four trials. Shrub lespedeza was included in one feeding trial, Crop Analysis II, and ranked fifth according to percent consumed.

Davison (1958) lists 138 quail foods as being either choice or inferior. Of the 11 food items that ranked first according to percent consumed in the feeding trials, 4 (wheat, rye, corn, and common ragweed) were classified as choice foods according to Davison's list. Two food items, oat and fall panicum, were classified as inferior according to Davison. Barley, yellow foxtail, red clover, soybean, and smooth sumac were not included in Davison's list of choice or inferior foods.

Of all items presented, corn, wheat, rye, and smooth sumac were most readily accepted in the feeding trials, and bluegrass, broom-sedge, and barnyard grass were least acceptable. Smooth sumac, which was presented in two feeding trials, Permanent Cover and Miscellaneous, ranked first according to percent consumed in both instances. This acceptance of smooth sumac would tend to support the views of Korschgen (1952) that sumac may be more than a starvation food and when combined with other foods may play an important role in the diet of the bobwhite.

SUMMARY

Adult, pen-reared bobwhites were used to compare the consumption of 41 various seeds presented in 12 cafeteria style feeding trials. Ten different seeds were used in each of 12 feeding trials. A group of quail maintained on cracked corn was used as a control during each feeding trial. Consumption of seeds and changes in weight varied with different feeding trials. Bobwhites accepted to some extent all foods presented in this study. The volume of seeds presented influenced consumption, and there were preferences for some seeds. Repeated feedings of some items resulted in an increase in consumption of these items. Items that were depleted during the course of the feedings were usually those that ranked high in percent consumption. The tests indicated that cereal crop seeds and smooth sumac were generally the most readily consumed.

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RESEARCH PROBLEMS IN WILDLIFE ADMINISTRATION

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The spectacular expansion of wildlife research by state and federal agencies over the past quarter century has raised new and unfamiliar problems for wildlife administrators. Research goals differ sufficiently from those of the standard operational practices that many administrators have had difficulty in making most efficient use of research staffs. In view of the common interest of biologists and administrators in research results and in the utilization of the research staff, the development of a sound research policy is a matter of general concern. The present paper raises some common problems facing administrators and their research staffs and suggests possible solutions that might be of interest to both groups.

The major problem of the administrator in building a research staff is that of personnel selection. It appears that staff deficiencies observed in many agencies are traceable to (1) failure to appreciate the complexities of modern research, (2) lack of appreciation of benefits resulting from adequate graduate training, (3) inability to set salary schedules adequate to attract and hold competent staffs, and (4) lack of recognition of the relative value of research as contrasted to administrative responsibility.

Wildlife research had its beginnings with the great naturalists, most of whom made their greatest contribution in the late nineteenth and the early years of the present century. Their work involved observation of animals in their natural habitat, collection of museum specimens, careful noting of animal habits and behavior patterns, analysis of crop and stomach contents, and interpretation of nature in terms of a few simple rules. We owe a great debt of gratitude to these men. Their enthusiasm was unquestioned, as was their love of nature. Their powers of observation were keen, and their discipline in careful record keeping and techniques left little to be desired for the task they performed. It is to be hoped that these qualities persist in their successors.

Many of the naturalists, however, differed from the layman more in interest than in research training. They often were deficient in a knowledge of animal psychology, the physiology of the animals studied, including nutrition, reproduction, and the role of endocrines, the biochemical interpretation of these phenomena, the mathematical approach to sampling, including recognition of inherent bias in some methods, appraisal of the significance of findings, and endless other essential tools of modern biologists. The Bachelor of Science today receives an introduction to these tools but they are sharpened and perfected to varying degrees by graduate study and research training.

Today's wildlife research, if it is to go beyond that of the nineteenth and early twentieth centuries, must be based on use of modern scientific disciplines and techniques. It is questionable that this goal can be attained by a research staff in which no member has the preparation at least equal to that represented by the doctoral degree.

If training at this level is expected, the administrator must be willing to struggle for salary schedules adequate to attract men capable of attaining the advanced degree. Graduate students in selecting a field for study undoubtedly are influenced to a large extent by opportunities, both financial and cultural, for advancement. If salaries in wildlife research continue to be far below those in such fields as chemistry, physics, medicine, and engineering, we must be content to take many men who for some reason have not been successful in meeting the requirements of the more lucrative competing fields.

When a research staff has been assembled, the administrator must decide

whether highly successful research men will be more valuable as researchers or administrators. If it is deemed desirable to maintain some highly competent men in research, then it must be possible for them to attain adequate recognition and compensation without transferring to administration. The Federal Civil Service Commission now recognizes that a high quality research man may be fully as valuable to his organization as his administrator and provides for high ratings for men doing research without administrative responsibility. This is a significant trend and should be adopted by other agencies. Too many men highly trained to conduct research, and eminently successful in advancing scientific theory, have been transferred to administrative positions which, although essential to advancement of the field, could be filled by competent men with less technical training.

In planning a research program, one of the most important decisions to be made involves the level of attack. We should perhaps ignore in this discussion such terms as "basic" or "fundamental" research, since they have become associated with the purpose of the investigator rather than with the depth to which he probes. Nevertheless, there has been a pronounced trend in agency research to attack such fringe problems as censusing of animals, compilation of food lists, estimating hunter kill, or evaluating the effects of hunting season regulations. It should be recognized that ignorance at any level can block the solution of wildlife problems. It is fully as important to know the significance of a food item in the physiology of the animal as to know that the item occurred in the animal's stomach. The interpretation at this level requires, as a basic minimum, a knowledge of physiology, and possibly of biochemistry. Furthermore, in setting up such an interpretive study some special skills may be required that are not necessary for mere food-habit analysis.

In selecting the level of research, the administrator should be guided by at least three factors: (1) the value of the expected findings in solving the major problem, (2) the ability of the research staff to go beyond the obvious in attacking a problem, and (3) the availability of sufficient personnel and scientific equipment to permit proper analysis.

It probably is inefficient to employ a staff of highly trained research men to attack simple observational problems which require only elementary experimental design and a minimum of interpretation. It is equally inefficient to expect the run-of-the-mill untrained man to conduct deep-digging, interpretive research. However, when a highly trained staff attempts to conduct complex research with so small a budget that it must depend upon outmoded or unreliable scientific equipment, we cannot expect efficient and reliable results.

It is the view of this writer that a well-rounded research staff should have both highly trained, experienced research men and adequate assistance by men with less training and experience. Such a staff should be provided with adequate funds for equipment and facilities to enable widest application of the senior men's planning and interpretive powers. With such a staff the administrator should encourage as much deep digging as possible so that fullest use can be made of the facts uncovered.

Given a good research staff with the privilege of delving deeply into important problems, productivity depends to a remarkable degree on worker morale. This, in turn, is strongly influenced by what we may call the research man's four freedoms.

1. Freedom to select detailed projects: It is essential in most agency research that major research projects be assigned rather than selected by the investigator. Staffs are selected to attack specific problems of interest to the agency, and practical aspects dictate that agency rather than individual interests predominate. Within the limits set by agency needs, however, there are opportunities for the individual initiative of the investigator to be expressed in the selection of aspects for study and the order in which they will be attacked. A well-trained research man prizes his initiative as one of

his major possessions. To the extent that he can preserve the idea of self-determination in his work he is likely to maintain a high level of interest in the project.

2. Freedom to plan: Planning of research is one of the major requisites of any program. It is important that the research worker be given every possible aid to help him develop a sound plan, which provides proper sampling of data capable of being analyzed and interpreted. Here, again, there is opportunity to permit the investigator to feel that he is the planner, with the assistance of other specialists, rather than merely a technician to carry out a plan prepared by someone else.

3. Freedom to publish and to take full responsibility for research: It must be acknowledged that not all men who conduct research want to prepare a published report. It is fully as clear that good research workers recognize the published record as an integral part of the research project. This is one basic point which distinguishes technicians from researchers. The fundamental purpose of research is to broaden the horizon of knowledge. This knowledge is based upon the literature, and the well-trained research worker considers his segment of work in relation to what others have contributed, in the hope that it may modify or clarify in some manner the common understanding of the problem under consideration. For this reason, it is beyond his comprehension that he should be expected to begin his research without adequate review of what others have contributed or close his project without preparing an adequate scientific report on his findings and their interpretation.

4. Freedom for scientific development: The scientific worker receives recognition less from the organization with which he works than from his fellow scientists, many of whom he may rarely see and knows only from the literature. The right of the research worker to participate in scientific societies, and to attend seminars and conferences of a purely technical nature, even though his administrator may find them of slight interest or value, is greatly cherished. In this way, many research men who are poorly paid and who are not recognized by their local agencies as more than routine workers, have established national reputations for competence because of their technical contributions. The administrator may do much to maintain high morale in his research staff by making conference attendance permissible at agency expense. The results, in terms of increasing growth by the scientist and new approaches to complex problems, will easily justify such expenditures.

The broad, elementary principles considered so far are fairly obvious. They are accepted as valid to a considerable degree by most progressive research agencies, even though too few have been successfully applied in most research programs. There are, however, some more subtle points in the administration of research on which there may be greater differences of opinion.

The first of these points arises from the dynamic nature of the scientific field. This condition exists especially in such new fields as wildlife biology in which change is the normal expectation. As examples over the past few decades, we need consider only such problems as the game farm, predator control, the buck law, rate of population turnover, refuges, and food patches as a few of many on which the thinking of game managers has been modified to a greater or lesser extent by research findings. In order to keep informed in such a mobile field, the research worker must spend many hours each week in searching the literature. Any research publication may contain a clue which the alert man can adapt to his own problem to give an entirely new perspective. It often is disturbing to the administrator to see the research man, who may have training far beyond that of the average of his staff, spend many additional hours in reading rather than on experimentation. The research man, admittedly, must do much of his reading "off the job"; yet it should be recognized that constant review is a valid part of his work. It is not possible for him to accomplish all this in evenings and on

weekends. Literature review should be encouraged by the insistence that an adequate amount of official time be devoted to this end.

Another point on which the research man may need direction is in consulting specialists in adjacent disciplines. Many researchers tend to be "lone wolves" in their approach to their problems, overlooking the progress made in related problems by scientists in physics, chemistry, pathology, or other associated fields. Most research centers regularly schedule consultations with scientists outside the immediate field of research in an attempt to obtain ideas of equipment or techniques which might be adapted to the problem at hand. A point which should not be overlooked is that the research worker is primarily an idea man and that he often must be pushed into situations where he will get new ideas. Too often, such men are allowed to become "men of action" rather than generators of ideas. To the extent to which the administrator can schedule or encourage seminars and interdisciplinary conferences, he may be injecting new vitality into his research staff.

The literature abounds with examples of brood counts, sex ratios, and other measurements in which the sample size is inadequate to give valid results. In many, if not most, of these studies, the investigator reported on all samples he was able to obtain. Nevertheless, preliminary planning and the advice of a competent statistician often show that obtaining an adequate sample is beyond the means at hand, or, conversely, that smaller sample sizes could be taken without sacrifice of reliability.

Bias in research usually does not result from carelessness or prejudice on the part of the observer. It may stem from misinterpretation of cause-and-effect relationships or, more commonly, from error arising from improper design of the experiment. One need not be a statistician to ferret out bias in program design; yet the statistician is especially trained to spot this type of error, and he can offer valuable criticism of the design before the experiment is performed.

It is not meant to imply that all research findings must be statistically significant in order to be useful. Nevertheless, the results of small samples often are extrapolated to indicate the condition of the entire population. In such studies, lack of statistical planning may result in unpardonable loss of scientific effort and money.

Some classical lines of wildlife study which no longer are likely to make a major contribution to science continue to hold the major interest of many research workers. Although still more can be learned on virtually any subject, it appears that some approaches, such as food-habits analysis, no longer have much possibility of advancing wildlife-management theory. The value of continued expansion of records of food items found in stomachs and crops, especially where there is no accompanying record of the ecological conditions under which they were selected or their relation to reproduction or other physiological processes, may be questioned. Live-trapping and tagging or banding continue to be emphasized in many studies, with little apparent thought devoted to techniques for wider or more reliable interpretation of results. A word of caution should be included to warn against too enthusiastic acceptance of new ideas before they are adequately tested. Science advances by systematic growth rather than by revolution. There is no added value in new methods merely because they are new. Some research workers appear to utilize new techniques and equipment to the extent that they become "gadgeteers" rather than seekers for facts. It is not the intention of this paper to encourage such a trend.

The role of leadership in stimulating research workers to improve their scientific output is not easy to evaluate. As one research station leader stated the problem, "If I must stimulate a scientist to produce, perhaps I need a new scientist." This statement is only half-truth. It should not be necessary to stimulate a research scientist to cause him to attack a problem with en-

thusiam. We need to recognize, however, that enthusiasm can be dulled by frustration if the research scientist too often is prevented from following fruitful lines of research because his administrative superiors fail to see its value. This is one of those gray areas in which every research administrator often finds himself uncertain as to what to do. If he approves every research proposal, the program may drift away from its charted course. If he refuses every one, the staff may suffer from lack of scientific interest. At the risk of seeming impractical, I suggest that some concession to research workers to permit work on projects that are questioned by the administrator may return dividends in increased enthusiasm as well as in unexpected scientific advances. The decision, of course, will depend upon the importance of the agency problem requiring attention, the potentialities of the research scientist, and the possibilities for success in the proposal.

At any rate, the supervisor in governmental agencies cannot get a new scientist whenever interest lags. Civil Service regulations are designed to select well-trained employees and to afford them protection on the job once they are selected. Consequently, the supervisor finds it easier to improve the output of his staff than to replace it.

As a step toward improvement of research morale, a wildlife research station should hold objectivity as one of its primary goals. This is not an easy goal to attain. Probably most of us can recall some of our college professors who, despite their insistence upon strict objectivity, were recognized by their students as being far from objective on some points. The research scientist, if he is to merit the title, must school himself at all times to approach each phase of an experiment with a cautious attitude as if he had no advance notion of its outcome. Furthermore, he must avoid the kind of interest in an observation that might predispose him to misread it in any direction.

achieve in a governmental research agency

Objectivity probably is more difficult to than in a university. Most governmental research projects are initiated because the administration has a special interest in the outcome. A state game department wants to justify its operational program; an agency wants the facts that would lead to stopping a practice judged to be detrimental to wildlife; or possibly the establishment of an expensive program depends upon facts tested in the research. Such conditions as these are unavoidable and need not mitigate against sound research. In such a situation, however, the research worker must be doubly cautious to avoid becoming emotionally involved in the problem to the extent that his judgment is unwittingly influenced.

The research worker who doubts that this could happen should test himself on some simple points, such as these:

(1) Am I as careful to check results when they turn out the way I expected as when they are contrary?
(2) Would I be disappointed if my hypotheses were not verified?
(3) In planning my research project, did I include phases the results of which might oppose my agency's program?
(4) In preparing the final report on a controversial project, am I free from any agency pressure, and do I tend to give as much weight to facts opposed to my agency's policy as to those which support it?

Whatever the investigator's attitude may be at the outset of a project, if he turns up facts early in the study that are used in criticism of an important program, he is likely to be brought under fire. At this point he will probably take up a position defending his viewpoint and opposing the program. From then on, his objectivity on this matter will be subject to question.

In view of this danger, it should be standard policy for the research arm of any agency to avoid engaging in extension activities based on or utilizing its own controversial research findings. This is not a popular point of view, and many research biologists object to being sheltered from wildlife controversies; nevertheless, it is es-

sential if research is to avoid the suspicion of bias. The team approach, which has gained much headway in recent years, can make an important contribution to objectivity in addition to its other advantages. The inclusion of representatives of several varied disciplines in a research team provides potentialities for deeper probing on several fronts than ordinarily are within the capabilities of any one scientist and, at the same time, can help to avoid unobjective bias. Nevertheless, we should guard against the danger even in team research that some false assumptions will be included in the planning. Where this occurs, the various members of the team may support one another in false premises and make it still more difficult to remove bias.

The relative status of research and operating branches in the organizational hierarchy is important. If research is controlled by operational branches, undue pressure may be exerted to make the interpretation of results justify operational policy. An effective control of research is provided by critical review by other scientists. Results, if generally applicable, must be subject to duplication by others if they are to be accepted. Sound research findings should not be buried merely because they might embarrass someone in the organization.

In addition to holding to objectivity, a second step toward improving research morale is to resist the initiation of research solely for propaganda purposes. When pressure from a sportsmen's or legislative group becomes strong, there often is a temptation on the part of the administrator to initiate research as a diversion even though no valid project is in order. He can then say, "We are conducting research on the problem." By the time the project is completed, with the anticipated lack of results, the pressure may have shifted to another quarter, or the problem may have disappeared.

There are several possible functions which a research staff can serve, within some of which lie insidious hazards. The legitimate function is to investigate factual relationships and to interpret cause and effect. To accomplish this, the research worker makes observations, formulates hypotheses, and proceeds objectively to test them, usually by sampling. When experiments are completed, he makes the necessary analysis, reports to his superiors, and prepares a manuscript for publication, which is then reviewed and criticized by his fellow scientists.

Such a procedure is time consuming. Few research projects are completed in less than a year, and many of them require several years. The final report and publication may require months to prepare. As mentioned above, the published report is a part of the research project, not something to be prepared in the interim between projects. Full time should be given for final reports to be prepared before the project is considered as closed.

The administrator of a governmental organization has an approach considerably different from that of his research men. His problems are ever changing. He must make daily decisions based upon accumulated evidence available to him and his staff. If there is insufficient evidence at hand for a clearcut decision, he must rely on personal judgment and the advice of his staff.

Occasionally he turns to his research staff for such advice. In this instance, their role differs from that of conducting research. That is, they are expected to reach a decision based on their knowledge of research results and their application to the problem at hand. The decision, nevertheless, may be credited as having validity because it comes from the research staff.

Another arm of most agencies is the educational or informational staff. It is a function of this group to appear before sportsmen's clubs or other organizations to talk about biological problems, organizational policy, or various natural history topics. The research worker may expect to be called upon to serve in this function, and except where he is expected to defend his research, there is no reason why he should not do so. Here extreme caution is more of a liability than an asset. The speaker who qualifies his remarks to the same extent that a research worker does his ideas in carrying out

a research project would fail to make his point with the audience. Consequently, he soon learns in this function to be positive. He must make strong statements based upon a minimum of evidence, and may become a master at defending a weak point in the policy of his organization.

A third function often assigned to the research staff is that of "troubleshooting." Often this staff contains the most highly trained biologists of the organization, and is generally assumed to be best qualified to apply scientific data to field conditions. Actually, because of the different skills that may be involved in the development of an idea and its application in the field, the most effective research worker may turn out to be relatively poor in field problems, whereas a poor researcher may excel in that function.

These extracurricular functions are accepted as normal parts of the research man's assignment. In some agencies, they may become his major duty. They impose upon him a real danger to the extent that the qualities they require contrast with those of the researcher. There should be no objection to the research worker becoming familiar with the application of his findings and the needs of his organization for the kind of contribution he is best qualified to make. The real danger is that the skills required for these other tasks may tend to interfere with the objective and cautious approach which he must maintain when he turns to research.

The chief value of a research staff to an agency is the scientific support such a staff provides to the agency's operations and policies. The value of the support depends to a great extent upon the reputation of the research staff, which in turn is largely a function of its technical competence and reliability. In order for the support to be substantial, the research staff must maintain a reputation for scientific objectivity and unbiased search for truth. Once this reputation is lost, it can never be entirely regained, and the value of the research arm to the agency is seriously reduced. Consequently, the administrator shares with the research group the need and responsibility for holding this part of his agency free from activities which may cause deterioration of respect among members of the scientific society.

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AGE CRITERIA AND POPULATION DYNAMICS OF THE SWAMP RABBIT IN MISSOURI[1]

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The purpose of this paper is fourfold: 1) to describe two age criteria for swamp rabbits (*Sylvilagus aquaticus*); (2) to present sex and age data for swamp rabbits; (3) to present statistics concerning hunting success and kill of swamp rabbits; and (4) to compare these data with published information about cottontails (*S. floridanus*).

Several publications describing aspects of the life history of the swamp rabbit have appeared in recent years (Lowe, 1958;

[1] Contribution from the Missouri Cooperative Wildlife Research Unit: University of Missouri; Missouri Conservation Commission; Edward K. Love Foundation; Wildlife Management Institute; and U. S. Bureau of Sport Fisheries and Wildlife cooperating. This is paper No. 4 from the Gaylord Wildlife Research Laboratory. Special thanks are due T. S. Baskett, Missouri Cooperative Wildlife Research Unit; H. M. Wight, Missouri Conservation Commission; J. E. Toll, U. S. Bureau of Sport Fisheries and Wildlife; W. H. Elder, and C. H. Conaway, University of Missouri. V. H. Skillings, Puxico, Missouri, and Arthur Case, University of Missouri, provided X-ray facilities and advice on radiographic techniques.

TABLE 1.—ESTIMATED AGES, EPIPHYSEAL CLOSURE DATES, AND CLOSURE PERIODS OF PENNED JUVENILE SWAMP RABBITS

Year	Tag No.	Sex	Date Trapped	Weight at Capture (g.)	Est. Age at Capture (mo.)	Closure Complete	Est. Closure Period (mo.)
1959	1,091	M	Nov. 4	1,250	4	June 18–25	11
1959	1,095	M	Nov. 22	1,840	5	May 4–11	11
1959	1,098	M	Dec. 8	1,539	5	June 18–25	11
1959	7	M	Dec. 14	1,703	5	June 18–25	11
1959	17	M	Jan. 29	2,185	6	May 4–11	10
1959	4	F	Dec. 14	1,816	5	June 18–25	11
1959	2	F	Dec. 18	1,165	4	*	–
1960	60	M	Nov. 7	1,559	5	May 28–June 3	12
1960	61	M	Nov. 6	1,772	5	May 20–27	12
1960	51	F	July 12	1,091	3	April 23–30	13
1960	52	F	July 13	964	3	April 23–30	13
1960	58	F	Oct. 18	1,885	5	April 23–30	10
1960	63	F	Nov. 9	1,233	4	*	–
1960	64	F	Nov. 12	1,772	5	May 18–25	11
1960	65	F	Nov. 13	1,899	5	April 29–May 6	10

* Epiphyses still open in late June.

Hunt, 1959; Toll, *et al.*, 1960). However, probably partly because of lack of a proven aging technique for this species, there is little published information concerning age and sex characteristics of swamp rabbit populations. Nor has any information been published regarding swamp rabbit hunting success or kill.

The present study was conducted on the Duck Creek Wildlife Management Area in southeastern Missouri. This area is managed primarily for waterfowl shooting; hence rabbit hunting is not permitted until the end of the duck season. This arrangement facilitates mass collection of data on swamp rabbits in a short period of time but also presents the problem of the adequacy of methods of age determination in rabbits taken this late in the season, i.e., during January and February.

METHODS

The experimental rabbits used in this investigation were captured with large treadle-operated box traps. No bait was employed. Twenty-seven juvenile swamp rabbits were captured; 15 were penned for observation and 12 tagged and released to form an unpenned group. The captive animals were kept in individual indoor cages and in a three-celled outdoor pen 30 ft. by 60 ft. These rabbits were fed a combination of commercial rabbit pellets and Ladino clover or vegetable scraps.

The progress of epiphyseal closure in these rabbits was noted from radiographs of the distal epiphyses of the radius and ulna made at regular intervals. A General Electric portable X-ray unit with a stand mount, Kodak dental occlusal film, 2 in. by 3 in., or Kodak no-screen film were utilized in the X-ray operation. The rabbit was placed in a canvas bag which had an opening through which the rabbit's right foreleg was extended over the film.

The penned rabbits were X-rayed at 2-week intervals from the date of capture (Table 1) until January. After January 1 the X-ray interval was shortened to 1 week and X-raying continued until closure of the epiphyses was evident in each individual. For purposes of comparison, epiphyseal closure in two penned cottontails was followed by means of radiographs made periodically in 1959.

Swamp rabbits bagged by hunters were checked at the Duck Creek Area Headquarters. The rabbits were sexed and weighed; and, when procurable, an eyeball, a forepaw, and reproductive organs from each were placed in a numbered vial containing formalin. In this manner, reproductive condition and lens weight could be

easily related to age as reflected by X-ray of the forepaw of each animal.

The eyeballs were left in the formalin for about 2 weeks to insure complete permeation of the preservative. Lenses were then removed and placed in a drying oven at about 80°C. The lenses were weighed each day until the weight loss was reduced to 1 percent or less per day.

AGE CRITERIA

The Epiphyseal Criterion

The epiphyseal technique for age determination in cottontails was first demonstrated by Thomsen and Mortensen (1946) and later refined by Hale (1949) and Petrides (1951). Closure of the distal epiphyses of radius and ulna in the swamp rabbit is essentially the same as that described by Petrides for the cottontail. In early stages the cartilage plates, appearing as black bands in the radiographs, are quite wide, and the margins of epiphyses and diaphyses of the bones are flared. As the rabbit matures the plates become narrower, gradually losing their identity completely as fusion of the epiphyses and diaphyses reaches completion. The black band indicating the cartilage plate is now lost and fine white longitudinal lines appear to be continuous across the region of fusion. Radiographs (Fig. 1) made by the authors illustrate this process and show the similarity of epiphyseal closure in swamp rabbits and cottontails.

During the 2 years of study, 15 juvenile swamp rabbits, 7 males and 8 females, were penned for the observation of epiphyseal closure. None of these animals showed complete closure prior to April 30 in either year and several remained identifiable as juveniles well into June.

Radiographs of the unpenned juvenile rabbits extended from January through March in 1959, and from November through February the following winter. None of these rabbits showed complete closure during the period observed. However, the rate of closure proceeded quite slowly and appeared to parallel the rate of closure in the captive group. This suggests that penning did not significantly affect the rate and/or the period of closure.

A primary objective of the age determination study was to determine whether young-of-the-year are still distinguishable from adults by the epiphyseal criterion in the months of January and February. All the experimental rabbits observed, 27 from both penned and unpenned groups, were identifiable as juveniles throughout these months. As stated above, the 15 penned rabbits retained their identity as juveniles much later than this. These observations indicate that the epiphyseal criterion was adequate to determine the gross ages of swamp rabbits in the large January–February collections at Duck Creek.

It is possible that some rabbits born earlier than those which we had under observation would show closed epiphyses by January or February. To explore this possibility, we estimated the ages at capture of the 15 penned juvenile swamp rabbits, added to these estimates the number of months after capture required for the completion of epiphyseal closure, and arrived at estimated ages at time of closure (Table 1).

The estimates of age at capture were based on body weights. This procedure is dubious because only fragmentary information about growth of young swamp rabbits is available. We assumed (1) a weight of 145 g. at the age of one month (Svihla, 1929); and (2) a daily increment of 13 g. thereafter (Hunt, 1956). Even though growth in weight was not linear, we were dealing mostly with a period of rapid growth, as was Hunt.

The principal danger in our procedure is possible overestimation of age of swamp rabbits at time of capture. To check this possibility, we calculated daily weight increments, assuming that the rabbits were 1 month younger than the estimated ages at capture shown in Table 1. The weight gains thus calculated ranged from 17 to 25 g. per day, and were considerably higher than published weight increments for the swamp rabbit (13 g.; Hunt, 1956), the cottontail (7.4 g.; Petrides, 1951), or the wild Euro-

FIG. 1. Epiphyseal closure in the swamp rabbit (top) and the cottontail (bottom).

pean rabbit (9.8 g.; Dunnet, 1956). The greatest weight increment for any individual swamp rabbit observed in this study was 10 g. per day. Although the estimates of ages of these rabbits are based on fragmentary evidence, they are probably conservative.

A study by Toll, *et al.* (1960) in the Duck Creek vicinity disclosed little breeding activity before late February; consequently few litters would be expected before April. Kill records show that most rabbits taken on this area are bagged by mid-January and only an occasional rabbit is taken during February. Thus most juveniles are shot before they are 10 mo. old. According to our estimates, 10 mo. is a minimum figure for the age of swamp rabbits at the time of epiphyseal closure. Thus, these estimates reinforce the strong indications from radiography of 27 rabbits that the epiphyseal criterion for age determination in swamp

rabbits is valid at least for January collections at Duck Creek. The January collections annually comprise over 95 percent of the total kill.

Concurrently with the 1959 study, epiphyseal closure in cottontails from this area was checked. A male and a female cottontail were penned and the progression of epiphyseal closure was observed in these animals. Complete closure was attained at about 7 mo. of age in the male and at 8 mo. in the female. Thus closure periods observed in these cottontails were 2 to 3 mo. shorter than in the swamp rabbits and approximated the term of 7 mo. established elsewhere for cottontails (Petrides, 1951; Wight, 1957).

The Lens as a Criterion for Age Determination

Krause (1934) demonstrated that the lens of the eye continues to grow throughout life in the domestic rabbit. His work disclosed little difference between the weights of paired lenses and between the lenses of the male and female of similar age and strain. Lord (1959) developed a dry-weight growth-rate curve for the lens of the cottontail which is suitable for estimating the age of wild rabbits whose lenses are removed, oven-dried, and weighed.

An investigation of lens weight as an aging criterion for the swamp rabbit was initiated in the present study. The data depicted in Fig. 2 represent lens weights of 145 swamp rabbits collected from December 3, 1959 to March 6, 1960. Although rabbits were collected over a 95-day period, 129 (90 percent) of the sample were taken during an 11-day period commencing December 26.

The weights of the swamp rabbit lenses were distributed within a 175.4-mg. range and may be grouped by epiphyseal age as follows:

Juvenile lenses	128.2–205.0 mg.
Adult lenses	212.8–303.6 mg.

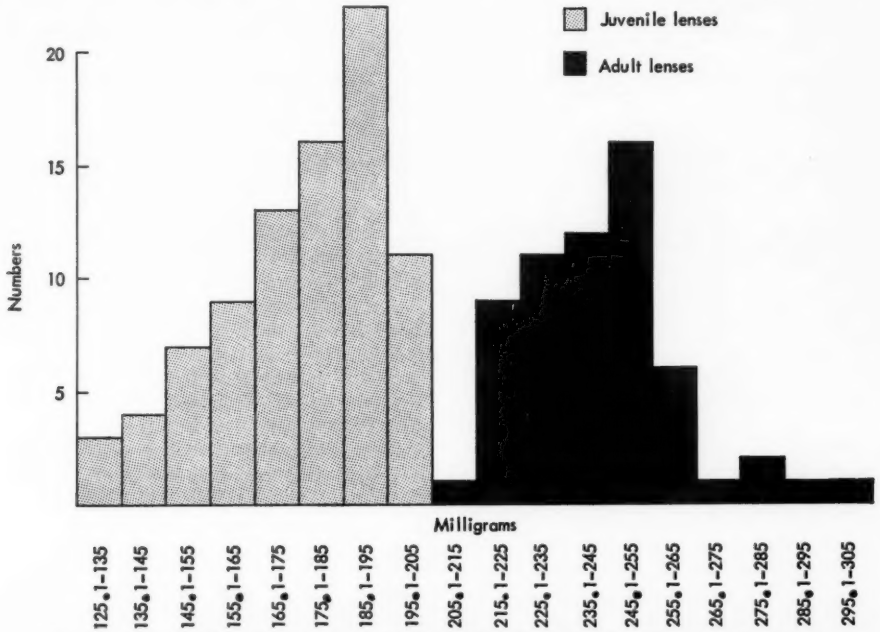

FIG. 2. Lens weights of 145 swamp rabbits shot from December 3, 1959 to March 6, 1960.

Thus there was no overlap in weights of juvenile and adult lenses; in fact a gap of 7.8 mg. exists between the maximum weights of the juvenile lenses and minimum weights of the adult lenses. Furthermore, if only the 129 individuals collected from December 26 to January 5 are considered, the heaviest juvenile lens weights are then separated from the adults by 11.2 mg. (The juvenile lens weight of 205.0 mg. is from a rabbit collected February 21, 1960.)

The results of this study suggest that lens weights are a valid criterion for distinguishing adult from first-year swamp rabbits. Furthermore, since lens weights were grouped according to epiphyseal age, the pattern of lens weights serves to reinforce the validity of the epiphyseal closure technique.

SEX AND AGE RATIOS

Sex Ratios

The determination of sex ratios in the swamp rabbit, as in other game species, is complicated by the methods used in the collection of data. For instance, the consensus is that cottontail sex ratios approach 50:50, but most samples show an unbalanced ratio. Presumably because of a tendency of females to hole up during cold weather, samples of cottontails shot during the winter usually favor males, while trapping or ferreting at this same time may produce more females (Elder and Sowls, 1942; Petrides, 1951). Sample size, regardless of the method of collection, undoubtedly plays a very important role in the analysis of sex ratio data.

Samples of swamp rabbits shot during the hunting season on the Duck Creek Area (Table 2) indicate a slight preponderance of males. Although the weighted mean percentage of males for 4 years is 55, this percentage has decreased each year; by 1960 males constituted only 49 percent of the sample. Hunt (1959) found 42.7 percent males in 152 swamp rabbits shot during the entire year in Texas.

A sex ratio based on swamp rabbits trapped during three seasons on the Duck Creek Area shows a predominance of females. Among 97 rabbits, 52 percent were found to be females when trapping data from Toll's (1958) study and the present study were combined.

Combining data from rabbits shot during the January–February hunting season, rabbits shot during all seasons, and trapped rabbits, Toll found a near 50:50 sex ratio among 254 Missouri swamp rabbits. This collection included: (1) the combination of methods of take, and (2) relatively large sample size, which were suggested by Elder and Sowls (1942) as necessary to demonstrate a true sex ratio in cottontails.

Age Ratios

The collection of swamp rabbit age data was initiated at Duck Creek by Wight in 1956 and although several workers gathered this information in subsequent years, age determination was rechecked by Wight each year.

The January–February swamp rabbit age ratios (Table 2), perhaps our best measure of productivity, indicate a maximum of 63 percent juveniles in any year.

The ratios of juveniles per adult female in Table 2 may not be representative of the population because of the small number of adult females. For example, the 1957 and 1958 collections included only 11 and 12 adult females, respectively. However, severe flooding during the spring of 1957 may have been responsible in part for the low ratio in 1958 (Conaway, *et al.*, 1960). There were 22 adult females in the 1959 collection and 23 in 1960.

Most published cottontail age data re-

TABLE 2.—SEX AND AGE RATIOS OF SWAMP RABBITS, JANUARY–FEBRUARY COLLECTIONS, DUCK CREEK, 1956–60

Year	Number	Sex Ratio (percentage of males)	Age Ratio (percentage of juveniles)	Juveniles per Adult Female
1956	44	–	43	–
1957	93	61	62	5.3
1958	59	56	56	1.9
1959	143	52	63	3.5
1960	142	49	61	3.3
Mean	–	54	61[1]	3.5

[1] The 1956 percentage is excluded.

TABLE 3.—AGE RATIOS OF SWAMP RABBITS AND COTTONTAILS

Species	Locality	Sample Size	Percent Juveniles	Collection Period	Authority
Swamp rabbit	Texas	152	32	12 months	Hunt (1959)
Swamp rabbit	Mo.	143	43–63	Jan.–Feb. 1956–60	This study
Cottontail	Mo.	928	59	mid-July 1952	Wight (1959)
Cottontail	Mo.	1,034	76	mid-July 1955	Wight (1959)
Cottontail	Ala.	147	75	Sept.–Nov. 1953	Majors (1955)
Cottontail	Ky.	504	80	Nov. 10–Jan. 10, 1951–52	Bruna (1952)
Cottontail	Wis.	339	79	Nov. 1–Jan. 15, 1944–46	Hale (1949)

veal higher percentages of juveniles than do these swamp rabbit data (Table 3). However, the relatively short duration of the validity of aging criteria has necessitated the collection of cottontail age data either in midsummer roadside counts, based on body size (Wight, 1959), or during fall and early winter, based on epiphyseal closure. Therefore, these data are not truly comparable with the January–February swamp rabbit age ratios.

Hale (1949) and Bruna (1952) reported age data for cottontails collected as late as mid-January. Both investigators employed the epiphyseal method but used the proximal portion of the humerus, a region where epiphyses remain open somewhat longer than at the distal ends of the radius and ulna. Their data are most nearly comparable with the Duck Creek swamp rabbit age ratios, but show much higher percentages of young.

Hunt (1959), collecting during all seasons, found 32 percent of 154 swamp rabbits to be juveniles. This statistic is not comparable to our data since Hunt averaged the results of 12 months of collecting.

LONGEVITY AND POPULATION TURNOVER

In a stable population the annual number of deaths (annual mortality) is equal to the annual number of young-of-the-year animals surviving to maturity. The relationship of average longevity (L) in a stable population in the spring and its average percentage of young (j) is expressed by the formula

$$L = \frac{100}{j}$$

Petrides (1949) has shown how this formula may be used for pheasants.

In the present study only the population data for the years 1957–60 were considered. The 1956 data were excluded because: (1) they represented an essentially un-shot population, since the area had been closed to hunting for several seasons; and (2) the sample of rabbits aged that year was very small. The mean percentage of juveniles for the years 1957–60 is 61. If it can be assumed that the Duck Creek swamp rabbit population is stable and that the average percentage of juveniles is 61, then:

$$L = \frac{100}{61} \qquad L = 1.6$$

Thus, on the Duck Creek Area the average longevity of swamp rabbits that survive until the shooting season is 1.6 yr.

The turnover period in an animal population is defined as the length of time required for a generation to be entirely replaced by its descendants; or for practical purposes, to 0.5 percent of their original numbers. Again if we assume stability in this population and apply another of Petrides' formulae, the population turnover period (T) in years is:

$$T = \frac{\text{Log } 0.005}{\text{Log } (1-j)} + 1 = \frac{\text{Log } 0.005}{\text{Log } (1-0.61)} + 1$$

$$= \frac{\text{Log } 0.005}{\text{Log } 0.39} + 1 = \frac{-2.301}{-0.409} + 1 = 6.6 \text{ yr.}$$

The calculated turnover period (T) of 6.6 yr. is the time necessary for a population of 100 swamp rabbits to be reduced to 0.5 rabbit. Although this is an artificial figure and the population is not stable, Petrides'

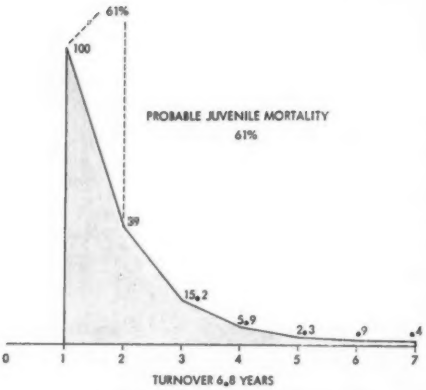

FIG. 3. Population turnover for 437 Missouri swamp rabbits collected 1957–60.

formula does provide an approximation of turnover period and mortality rate.

Fig. 3 shows the population turnover picture for Missouri swamp rabbits in graphic form adapted from Leopold, *et al.* (1943). The computation was based on data from 437 swamp rabbits collected during 4 years.

FACTORS AFFECTING PRODUCTIVITY AND TURNOVER RATES

Juvenile Breeding

Juvenile breeding in the cottontail has been reported frequently in the literature (Ingles, 1941; Hendrickson, 1947; Bruna, 1952). Recently it has become apparent that a considerable number of juveniles may breed in their first summer. Lord (1958), expressing the number of juvenile breeders as a percentage of the breeding female population, found 55 percent in the month of August and 76 percent in September in Illinois. Negus (1959) found 42 percent of 67 subadult female cottontails reproductively active in Ohio.

Only one instance of juvenile breeding has been reported in swamp rabbits. Hunt (1959) found one pregnant animal that he classified as a juvenile on the basis of its small body size. However, Hunt noted year-long breeding on his study area in Brazos County, Texas, and this reproductive pattern may enhance the chances for breeding in young animals.

Uteri from 23 adult and 55 juvenile swamp rabbits were collected during our study. The uteri taken from adults, with one exception, retained placental scars. In general, these tracts were larger than those from juveniles and were "strap-like" in form. Several uteri taken from juveniles were as large as those from adults but exhibited neither placental scars nor the "strap-like" characteristic. On the basis of these criteria, none of the 55 juvenile female swamp rabbits, which were aged by the epiphyseal method, showed evidence of full-term pregnancies during their first summer. Certainly the age ratios (Table 2) exhibited by this population do not suggest an addition to productivity such as juvenile breeding. Furthermore, if the long gestation period of the swamp rabbit is taken into account (40 days; Hunt, 1959), it may be that the breeding season in Missouri is too short to permit breeding in first-summer animals.

Hunting Mortality

Statistics on rabbit hunting on the Duck Creek Area have been available since 1956. These statistics are presented in Table 4.

The total acreage hunted on the Duck Creek Area has not been constant from year to year. Seven-hundred and fifteen acres of swamp rabbit habitat were available each year plus portions of duck shooting pools in various stages of flooding during the rabbit season. These pools were flooded in October in preparation for the waterfowl flight and drained after the shooting season. In 1956 and 1957 an upland area was included in the huntable acreage. No swamp rabbits occurred there but the area contributed a considerable portion of the total cottontail kill and hunter success was probably high.

During the first season of rabbit hunting on the Duck Creek Area (1956) there was very heavy hunting pressure and a relatively high kill of swamp rabbits. Hunter success was high and swamp rabbits appeared to be numerous in the area. Al-

TABLE 4.—HUNTING STATISTICS, DUCK CREEK AREA, JANUARY–FEBRUARY SEASONS, 1956–60

	1956	1957	1958	1959	1960
Hunters	1,043	536	145	201	307
Hunter-hours	3,661	1,883	533	875	1,128
Swamp rabbits shot	709	192	67	151	147
Cottontails shot	375	188	28	65	50
Kill per gun hour (both species)	0.30	0.20	0.18	0.25	0.17
Kill per gun hour (swamp rabbits)	0.20	0.10	0.13	0.17	0.13
Rabbits shot per acre (both species)	0.70	0.30	0.10	0.14	0.14
Swamp rabbits shot per acre					0.11
Percentage of juvenile swamp rabbits	43	62	56	63	61

though the sample size was small, age ratios among these rabbits were the lowest recorded to date: 43 percent juveniles. This phenomenon may be attributable to land and water manipulations on the area prior to its opening for hunting. Recent logging operations had left the area in a condition highly beneficial to swamp rabbits and probably had the effect of creating a high density of rabbits in this area. The main reservoir, an area of 1,773 a. of swamp rabbit habitat, was flooded November 18–December 28, 1954, or just prior to the 1955 breeding season.

The two duck-shooting pools, 1,284 a. in extent, were test-flooded for a period of about 30 days during January and February 1955. These duck-shooting pools were again flooded in October 1955 in preparation for the waterfowl season and remained inundated through the beginning of the rabbit season, January 1956. The effects of these water manipulations were twofold. The earlier flooding, during the winter of 1954–55, may have had the effect of lowering reproductive rates through crowding of the swamp rabbits prior to the 1955 breeding seasons.

Conaway, *et al.* (1960) hypothesized that a high incidence of total litter resorption noted later in this area may have been induced by crowding. Water manipulation also appears to have had the effect of raising the kill and hunter success. Flooding of the main reservoir evicted rabbits from that area, and fall flooding of the duck-shooting pools, by crowding swamp rabbits on ditch banks and other emergent areas, made them more vulnerable to hunting.

Another interpretation of the high kill of 1956 should be considered; viz., the area had been previously closed to hunting for several years and this may have resulted in an unusually high density of swamp rabbits.

Although most authorities feel that shooting has little effect on populations of cottontails (Pirnie, 1949; Wight, 1959), the lower productivity of swamp rabbits (indicated by lower age ratios, the effect of smaller litters, longer gestation, and a probable lack of juvenile breeding, at least in Missouri) may result in a species more noticeably affected by gunning.

After 1956 the total swamp rabbit kill seems to have leveled off at about 100–200 per year. The exception is the 1958 season when only 67 swamp rabbits were taken. The obvious cause of this lowered bag was the paucity of hunters. In addition, during the spring of 1957 extensive flooding occurred over the entire area and much crowding occurred in this swamp rabbit population. According to the findings of Conaway, *et al.* (1960) this crowding may have been responsible for reduced productivity during the 1957 breeding season and, in turn, the low total bag for the subsequent 1958 hunting season.

Further analysis of kill and its relationship to hunter success and age ratios is complicated by multiple factors. The quality of the habitat for swamp rabbits has gradually deteriorated through plant succession and the breakdown of brush piles. The terrain hunted has been changed; i.e., the upland area was excluded from the huntable acreage after 1957. And finally, the special conditions imposed by intensive

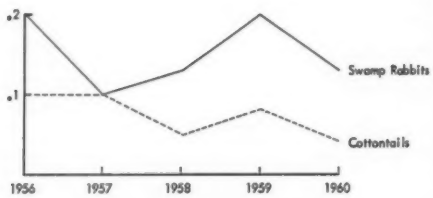

FIG. 4. Rabbits killed per gun hour.

late season hunting complicate the relationship between swamp rabbit density, total bag, and hunter success. Since hunters are entering an unshot area at late season and many have traveled considerable distances (Toll, 1958), it may be that their hunting efforts are continued despite low success and this phenomenon tends to lower hunter success.

A tentative comparison of the effect of hunting on cottontail and swamp rabbit populations can be made by employing hunter success and kill data (Figs. 4 and 5). During the 1956 and 1957 hunting seasons, the huntable acreage included an upland area of good to excellent cottontail habitat. The response of the crowded swamp rabbits and a nearly "normal" cottontail population can be detected in the kill and hunter success figures. Hunter success for swamp rabbits dropped 50 percent in 1957 but cottontail success held steady. Total kill of swamp rabbits fell nearly 73 percent but cottontail kill decreased only about one-half.

After 1957 the upland area previously mentioned was excluded from the huntable territory and during the following years the area hunted included only swamp rabbit habitat and marginal cottontail habitat. Hunter success for swamp rabbits paralleled that for cottontails in 1958–60 (Fig. 4). Cottontail kill and swamp rabbit kill show this same relationship (Fig. 5) and fluctuate in a manner similar to the success figures; i.e., the kill figures increase or decrease as do the success data. Perhaps this indicates little interspecific difference in response to hunting on this area of good swamp rabbit habitat and marginal cottontail habitat.

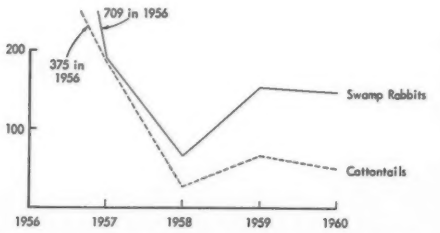

FIG. 5. Total kill of swamp rabbits and cottontails.

Hunter success for swamp rabbits on the Duck Creek Area is relatively low. The date of the open hunting season may cause the low hunter success; i.e., swamp rabbit populations would be expected to be at a low level so late in the season. Futhermore, the habitat of timber, swamp, and thickets, and possibly a reduced number of swamp rabbits per unit area in this type of habitat combine to make the species difficult to bag.

SUMMARY

This study of a swamp rabbit population was made on an area in southeastern Missouri. Radiographic observation of the epiphyseal closure in the radius and ulna was made on 15 penned juvenile swamp rabbits. Complete closure was not observed in any of these animals prior to April. Estimated epiphyseal closure periods for penned swamp rabbits ranged from 10 to 13 mo. Dry weights of lenses from 145 swamp rabbits were classified according to the epiphyseal age of the rabbits. Lens weights from juvenile swamp rabbits occurred in a range of 128.2–205.0 mg.; those from adults in a range of 212.8–303.6 mg. The mean percentage of males for 4 yr. of hunting season data was 55. Trapping revealed 52 percent females. Age ratios of swamp rabbits increased from 43 percent juveniles in 1956 to 63 percent in 1959. Average longevity for this swamp rabbit population was calculated to be 1.6 yr. Gross examination of uteri from 55 juvenile swamp rabbits showed no indication of juvenile breeding. Hunting success varied from 0.2 to 0.1 swamp rabbits bagged per gun hour over a 5-year period. Swamp rabbit kill was high-

est in the first open season on the study area, and lowest in a season following extensive spring flooding.

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EDITORIAL NOTE

The names of several colleges or universities offering training for fishery biologists and wildlife biologists were inadvertently omitted from the listing of such institutions on pages 195–197 of The Wildlife Society Special Report, "Training and Employment of Wildlife Biologists and Fishery Biologists," Vol. 25(2): 190–199 of this journal. The Editor and The Allen Press will cooperate to correct the oversight by making additions to the type which is being held for reprints.

Additional colleges or universities offering training for wildlife biologists and fishery biologists, and that should have been listed, are:

Montana State College (Bozeman, Montana)
Department of Zoology and Entomology
B.S. (Fish and Wildlife Management); M.S., Ph.D. (Major in Fisheries and Wildlife Management).

Montana State University (Missoula, Montana)
Department of Zoology
B.S., M.S. (Wildlife Technology); B.A., M.A., Ph.D. (Zoology)
School of Forestry
B.S. (Wildlife Conservation); M.S. (Wildlife Management).

New York State University of, College of Forestry (Syracuse, New York)
Department of Forest Zoology
B.S. (General Forestry–Biological Sciences); M.S., Ph.D. (Forest Wildlife Management).

North Carolina State College (Raleigh, North Carolina)
Department of Zoology
B.S., M.S., Ph.D. (Wildlife Biology); M.S., Ph.D. (Animal Ecology).

AIR-INDUCED WINTER CIRCULATION OF TWO SHALLOW MICHIGAN LAKES

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The prevention of periodic winterkills of fish in shallow, eutrophic lakes has been the object of considerable interest for many years. It is generally agreed that depletion of dissolved oxygen under the ice late in winter is the fundamental cause of winterkills (Greenbank, 1945; Cooper and Washburn, 1946; Scidmore, 1957). Greenbank listed a number of possible remedies proposed by various workers which included (1) diverting a flow of water into the lake, (2) raising the water level, (3) cutting holes in the ice, (4) pumping air into the water, (5) vegetation removal, and (6) snow removal.

In recent years workers have experimented with compressed air as a means of rejuvenating the oxygen supply in a lake (Hemphill, 1954; Schmitz and Hasler, 1958; Schmitz, 1959; Burdick, 1959; Rasmussen, 1960). The release of compressed air through a series of holes in an air conductor laid on or near the bottom of a lake creates vertical currents which bring the warmer bottom water into contact with the ice cover. Holes are melted through the ice and shortly thereafter a channel of open water is created above the air conductor. This opening allows water to come in contact with the air and absorb oxygen from the atmosphere.

The feasibility of preventing winterkill of fish in a lake by the use of compressed air was tested in two lakes subject to winterkill conditions at the Rifle River Fisheries Research Station, Ogemaw County, Michigan. Spring and Loon Lakes were selected because of their past history of winterkills. Both lakes are located within 100 yd. of a source of electricity for operation of a compressor.

Spring Lake is a rich, shallow, 72.5-a. lake which contains an abundance of aquatic vegetation (Fig. 1). An intermittent outlet connects this lake with Loon Lake; there is no well-defined inlet. Spring Lake was selected for exploratory work in the winter of 1957–58 because of the greater probability that an oxygen deficiency would develop here than in Loon Lake. Frequent winterkills had virtually eliminated yellow perch (*Perca flavescens*), the only important game species, leaving only large populations of black bullheads (*Ictalurus melas*) and forage fish (chiefly northern redbelly dace, *Chrosomus eos*). No special effort was made to prevent winterkill in the entire lake. The air conductor was merely installed across one end of the lake, where the effects could be observed.

During the winters of 1958–59 and 1959–60 the work was performed in Loon Lake. This 16.8-a. lake (Fig. 1) has an abundance of aquatic vegetation, a soft bottom of organic ooze mixed with marl, and a fish population composed principally of largemouth bass (*Micropterus salmoides*) and a number of species of pan fish. Both the inlet (from Spring Lake) and the outlet are intermittent. Although attempts to prevent winterkill conditions in Loon Lake were unsuccessful, the experiments demonstrated how the temperature and oxygen regimes beneath the ice are affected when an aerator is used, and pointed out some of the difficulties which might be encountered in using compressed air.

Frank F. Hooper suggested the project and advised on certain procedures. Arthur W. DeClaire assisted in setting up the equipment and performed most of the oxygen analyses in 1959 and 1960. Other station personnel who assisted in various phases of the project included Howard Gowing, Charlie J. Kohn, Keith R. Sammons, and George Smith, Jr. Gerald P. Cooper, Paul H. Eschmeyer, Frank F. Hooper, and David S. Shetter read the manuscript and offered suggestions. Harold Hughes, Superintendent of Drayton Plains

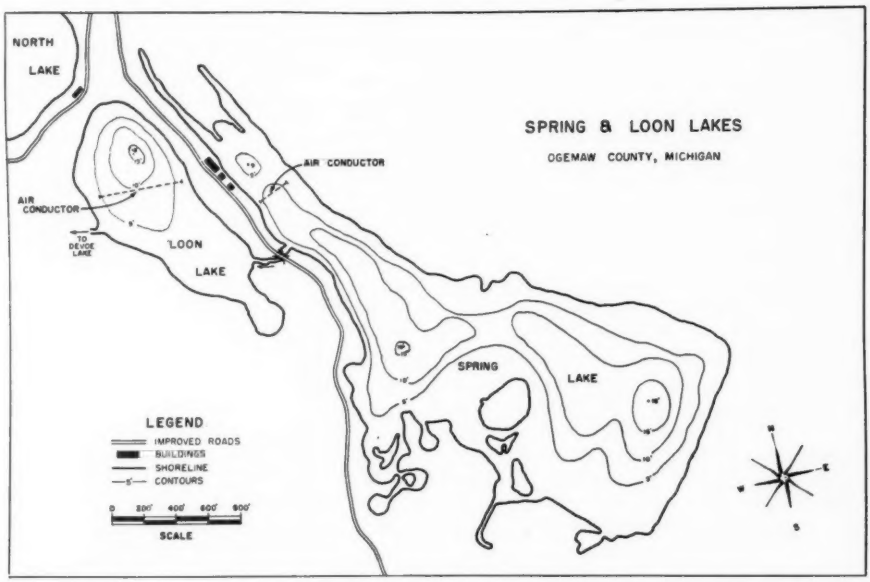

FIG. 1. Hydrographic map of Spring and Loon Lakes, Ogemaw County, Michigan, showing location of air conductors.

Fish Hatchery, provided an air compressor for the work. William C. Cristanelli and Paul M. Earl prepared the illustrations.

METHODS

Methods and equipment used for circulation of water under the ice differed only slightly during the three winters of operation. In Spring Lake in 1957–58, a 250-ft. section of ½-in. (inside diameter) rubber garden hose was laid across the northern end (Fig. 1), where the maximum water depth is approximately 6 ft. The hose was perforated with 20 holes of 1/32-in. diameter at intervals of 12½ ft. and weighted with 8-ft. sections of ¼-in. steel rod (about 3 lb. per 25 ft. of hose). The distal end was plugged so that no air could escape. Both ends of the hose were tied to stakes which protruded from the water, thus marking location of the hose. A 300-ft. length of hose connected this line to the air compressor, which was housed in a workshop. The air compressor used was an electrically powered DeVilbiss compressor of 4 to 5 cu. ft./min. capacity, a type of unit commonly used in gasoline stations or commercial garages. It was operated continuously from February 24 to March 26, 1958. A smaller auxiliary compressor (capacity unknown) was also hooked into the system and used frequently. Preliminary trials, after a 4½-in. ice cover had formed early in December, revealed that the perforations in the air line were too small to prevent frequent stoppages. Enlargement of the holes to 1/16 in. and insertion of a basketball inflation valve in each hole corrected this difficulty.

Essentially the same equipment was used in Loon Lake in the winters of 1958–59 and 1959–60, except that the perforated hose was 500 ft. in length, and only 175 ft. of hose were necessary to connect the perforated line with the compressor. In 1958–59 the submerged hose lay on the bottom in water 3 to 10 ft. deep, but in 1959–60 it was suspended from wooden floats at a depth of 5 ft. The compressors were oper-

ated from December 30, 1958, to April 1, 1959, and from December 8, 1959, to March 14, 1960. A complication during the two winters of work at Loon Lake was periodic stoppage (about every 5 to 7 days) in the connecting line near the building, caused by freezing of condensation moisture. This required thawing out the frozen section each time that a stoppage occurred (usually whenever a relatively warm spell was followed by a night of near-zero temperature).

Two methods of laying the hose were tried during the three winters. In Spring Lake the hose was laid on the bottom prior to the freezeup. In Loon Lake (1958–59) a rope was laid on the bottom of the lake before the lake froze; after an ice cover had formed, the hose was stretched out on the ice, prepared for use, tied to one end of the submerged rope, and pulled across the lake under the ice. The method used in Spring Lake is preferable, especially if a long air line is used, or if there is danger of snagging the air line as it is pulled along the lake bottom.

In 1957–58, water samples were collected semiweekly at a series of stations in Spring Lake: one station in the open water, plus paired stations located 50, 100, 200, and more than 400 ft. from the open channel. The water samples were collected about 2 ft. below either the water surface or the bottom of the ice. All were analyzed for dissolved oxygen by the Winkler method.

In Loon Lake in 1958–59, a similar pattern of water sampling was followed except that two stations were established in open water and most of the water samples through the ice were taken at stations 200 ft. from the air hose. The Winkler method of oxygen analysis was again used. Several temperature series were taken in the open water and under the ice 200 ft. away with a Whitney resistance thermometer.

The following winter (1959–60) the sampling in Loon Lake was modified to the extent of obtaining samples above and below the 5-ft. level (depth of air conductor), and a Negretti-Zambra reversing thermometer was used to obtain water temperatures.

TABLE 1.—AVERAGE MONTHLY MAXIMUM AND MINIMUM AIR TEMPERATURES (°F.) TAKEN AT RIFLE RIVER AREA WEATHER STATION, DECEMBER–MARCH, 1957–60

Item	WINTER		
	1957–58	1958–59	1959–60
Maximum			
December	35.9	26.3	34.9
January	30.7	24.3	29.8
February	28.2	29.6	31.9
March	42.5	39.4	35.4
Minimum			
December	17.7	2.3	19.9
January	9.6	3.5	13.0
February	4.3	0.0	9.8
March	21.5	13.0	6.9

WEATHER CONDITIONS

The winter weather of 1957–58 and 1959–60 may be considered as normal for this vicinity, except that unusually cold weather in March 1960 delayed the breakup of ice cover (and the replenishment of oxygen). In 1958–59, however, mean monthly maximum and minimum temperatures in December, January, and February were mostly 6° to 16°F. below normal (Table 1).

In the winter of 1957–58 there were 23 nights of subzero temperatures, the coldest being –23°F. In 1958–59 the temperature dropped as low as –32° during a total of 44 nights of subzero cold. The lowest temperature recorded in 1959–60 was a –20°, and subzero temperatures occurred on 25 nights. Correspondingly, the number of days in midwinter (January and February) in which the temperatures rose above 32°F. was 24 in 1958, 18 in 1959, and 22 in 1960.

Snowfall was much greater in 1958–59 than in either of the other two winters. Total amounts for the 4-mo. period (December–March) were 32.5 in. in 1957–58, 63.0 in 1958–59, and 44.6 in 1959–60. The maximum accumulation on the ground was 14 in. in 1958, 26 in. in 1959, and 16 in. in 1960. On the lakes, however, the accumulation of snow was not so great because of wind activity. Maximum depths measured were 5 in. in 1958, 12 in. in 1959, and 6 in. in 1960.

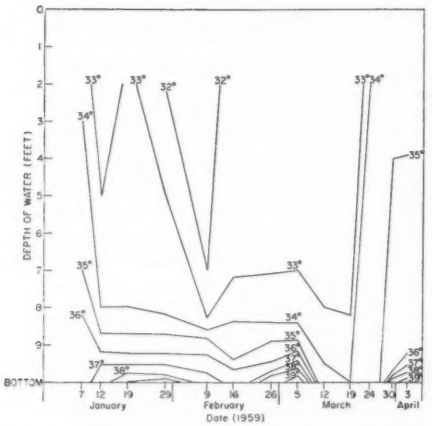

FIG. 2. Water temperatures (°F.) in Loon Lake, in the immediate vicinity of the air conductor, January 7–April 3, 1959.

ICE REMOVAL

An open channel from 10 to 20 ft. wide was created each winter about one week after the air compressor was started. Holes in ice as much as 15 in. in thickness were opened up overnight. In the severe winter of 1958–59, however, the channel in Loon Lake consisted only of a series of 5-ft. circles above the air holes in the hose during periods of extremely cold weather (10–32° below zero). The following winter (1959–60), between February 15 and March 11 the channel width was only about 5 ft. because of cold weather. The maximum ice thickness measured during these three winters was 23 in. (March 12, 1959).

WATER TEMPERATURE

Water temperatures (°F.) were taken frequently in Loon Lake in 1958–59, at 1-ft. intervals, commencing at a depth of 2 ft. below the surface and extending into 1 ft. of bottom ooze. On December 29, 1958, the day before circulation was started, water temperatures beneath the ice ranged from 35.4° at the 2-ft. depth to 39.9° at 11 ft.; the temperature of the bottom ooze was 42.6°. On January 7, after 8 days of water circulation, temperatures in the open water were only 33.8° at a depth of 2 ft., 35.9° at 8 ft., and 36.8° in the bottom ooze. The water temperature continued to drop and become more uniform with depth as operation of the air line continued. The wide spacing between the 32° and 34° isotherms in Fig. 2 reflects this uniformity. A protracted period of very cold weather between January 20 and February 9 culminated in supercooling of the open water. During this period the average minimum air temperature was –5.5° (range, 22° to –30°). On February 9 the open-water temperature ranged from 31.4° to 31.8° down to a depth of 6 ft.[1] On March 19 the temperature of the circulating water down to a depth of 8 ft. was a uniform 32.8°; below this level a gradual increase in temperature with increasing depth was observed. Most of the perforated hose lay at water depths of 8 to 10 ft. and the temperature at the 9-ft. level was slightly higher than in shallower water until March 24.

Beneath the ice 200 ft. away from the air line there was also a marked drop in temperature after the first week of operation. Temperatures ranged from 34.4° at a depth of 2 ft. to 37.1° in 8 ft. of water. There was a trend towards uniform temperatures within the 2- to 8-ft. stratum similar to that over the air line (Fig. 3); temperatures in this stratum differed by no more than 1.5 degrees for 45 days (February 16–April 1) and were at a minimum on March 19, when they ranged from 31.3° to 32.8° F.

In 1959–60, when the air conductor was suspended in Loon Lake at a depth of 5 ft., water temperatures above it varied less than 1.0° between January 29 and March 14. (Temperatures were not taken prior to January 29.) Similarly, beneath the ice 200 ft. away, less than 0.5° separated the temperature readings at the 2- and 4-ft. depths in February and March. On March 9 a

[1] When these unusually low temperatures were observed, the alignment of the Whitney thermometer was rechecked and the temperature series repeated with the same results. There was very close agreement, also, with readings taken at the surface with a pocket thermometer. Thus there is little doubt that there was true supercooling of the water at this time.

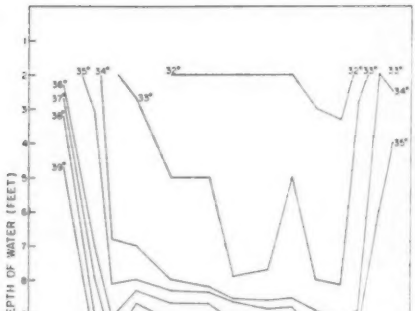

FIG. 3. Water temperatures (°F.) in Loon Lake, beneath the ice 200 ft. from air conductor, December 29, 1958–April 3, 1959.

minimum range of 32.0°–32.2° was recorded. Two temperature series taken in March, 400 ft. from the air conductor, disclosed the same uniformity. At all sampling sites water temperatures were much higher at greater depths (maximum, 41.7° at 14 ft.).

Thus it appears that the turbulence created by the rising air bubbles induced lateral currents similar to those which are generated by wind action during open-water seasons. These currents, together with accompanying eddy diffusion, formed an isothermal zone to a depth corresponding roughly to the depth of the air conductor. A narrow temperature gradient was established between the 8- and 10-ft. contours in 1959 and the 5- and 7-ft. contours in 1960. Temperatures of the warmer (and denser) water beneath this temperature gradient were less affected but were lowered gradually to 38.3° near the bottom (water depth, 13 ft.) on March 24, 1959. Virtually no change was detected at the 14-ft. depth in 1960, presumably because the temperature gradient formed at a higher level.

The temperature of the bottom ooze beneath the air conductor in Loon Lake in 1958–59 fluctuated considerably but gradually became colder, reaching a low of 34° F. on March 19, 1959, at a time when the water temperature also was at a minimum. Two hundred feet away the ooze-temperature decline was less pronounced but perhaps important to bottom fauna. There was a drop of 2.2° between January 29 and March 19, while in nearby Dollar Lake the temperature of the bottom ooze dropped only 0.7° in a similar period of time.

Schmitz and Hasler (1958) observed that, under summer conditions, an almost homoiothermal condition was produced within 4½ hr. in a 0.3-a. lake to a depth of 23 ft. A similar condition developed above the 8-ft. level in Loon Lake in mid-February 1959. Probably a noticeable temperature drop occurred shortly after circulation was started.

DISSOLVED OXYGEN

The principal question to be answered by this investigation was whether or not an adequate supply of oxygen could be maintained by artificially circulated water in a shallow Michigan lake subject to the winterkill of fish. Normally, the chief winter source of additional oxygen is photosynthetic activity of phytoplankton, but this process stops when snow covers the lake. Greenbank (1945) and others have shown that very little light is transmitted through a heavy covering of snow. These lakes were covered with snow continuously for approximately 3 months each year.

The start of the experiment in Spring Lake in 1957–58 was delayed until late in the winter to learn if it would be possible to rejuvenate the oxygen supply in the upper end of the lake. On February 24, before the compressor was started, the oxygen content ranged from 0.0 to 1.1 p.p.m. within 200 ft. of the air conductor, and averaged 2.6 p.p.m. at two stations 400 and 800 ft. away (Fig. 4). During the ensuing 26 days only a slight increase in dissolved oxygen occurred in the open water (maximum observed, 1.8 p.p.m.), despite a pronounced

rise elsewhere in the lake between February 26 and March 5 (caused by a thaw). Even at the 100-ft. stations a marked increase was detected, although this increase lagged behind that in other parts of the lake. It was apparent that the influence of the turbulent water extended no further than about 100 ft. at this time. The benefit from the February 26–March 5 thaw was short-lived. By March 7 the oxygen readings dropped back to pre-thaw levels. During the next 2 weeks the oxygen level remained quite uniform throughout the lake (mostly below 2.0 p.p.m.). Late in March the supply was replenished by the beginning of the spring thaw, but during this recharging period the open water above the air conductor was the last to be affected. These observations on Spring Lake suggested that oxygen absorbed from the atmosphere by the upwelling water was quickly consumed by biological processes.

In Loon Lake, on December 29, 1958, the oxygen content at two stations in the center of the lake 3 ft. below the ice ranged from 6.5 to 6.8 p.p.m. Water circulation was started the following day and water sampling was begun 1 week later, after a channel of open water had appeared. A marked downward trend in oxygen started the first week (Table 2) and continued until about March 20, when the spring thaw began. Since the dissolved oxygen 2 ft. below the ice appeared to be fairly uniform throughout the lake, sampling at the 50- and 100- ft. stations was done at irregular intervals after January 29, 1959. Semi-weekly sampling was done only in the open water and at two stations beneath the ice, 200 ft. on either side of the open channel.[2]

The results in both Spring Lake in 1957–58 and Loon Lake in 1958–59 suggested that the large demand for oxygen by decay processes in the rich, organic bottom sediments was too great to be overcome by the circulating water, and any oxygen absorbed from the air by the turbulent water was rapidly consumed; very little, if any, was retained in the upper strata. Thus, a low-oxygen condition could neither be pre-

TABLE 2.—MEAN OXYGEN VALUES (P.P.M.) AT PAIRED SAMPLING STATIONS IN OPEN WATER, AND BENEATH THE ICE 200 FT. FROM OPEN WATER, LOON LAKE, 1958–59 AND 1959–60 (Water samples taken at depths of about 4 ft.)

1958–59			1959–60		
Date	Open Water	Ice	Date	Open Water	Ice
Dec. 1958			Dec. 1959		
29[1]	–	6.7	7[1]	–	10.3
Jan. 1959			14	8.7	9.1
7	4.1	4.2	23	8.7	8.5
15	3.1	3.8	30	7.3	7.8
23	3.1	3.1	Jan. 1960		
29	2.1	2.3	4	7.0	5.6
Feb.			13	5.0	5.3
5	1.6	2.5	20	4.2	3.8
12	1.2	2.1	28	3.3	3.6
23	0.9	0.6	Feb.		
Mar.			3	3.2	3.1
2	0.6	1.1	11	2.8	2.5
9	0.9	1.2	17	1.7	1.8
16	1.0	1.0	Mar.		
20	0.4	5.2	3	1.2	1.1
26	1.5	4.0	14	0.5	0.5
Apr.			18	–	0.4
1	2.3	6.1	31	–	1.7

[1] Samples taken before air compressor was started.

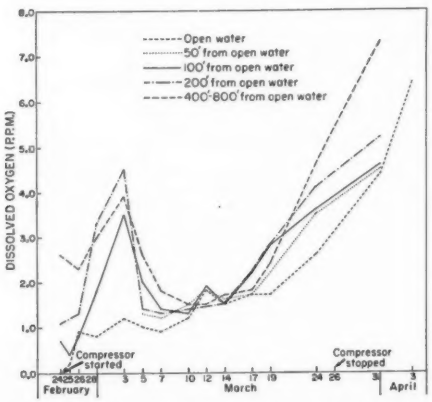

FIG. 4. Oxygen values at sampling stations in open water, and beneath the ice, Spring Lake, 1958.

[2] Although most water sampling was done 2 ft. below the bottom of the ice, a few deeper samples were taken in both open water and at the 200-ft. stations. These data indicated a uniform deficiency of oxygen in open water, but beneath the ice the oxygen content at 10 ft. was 0.5 p.p.m. lower than at the 2-ft. level on March 12 and 3.8 p.p.m. lower on March 30.

vented nor corrected in either lake by the methods employed. Furthermore, the rapid decline of oxygen in Loon Lake in 1958–59 during the first week following the start of circulation implies that oxygen depletion was accelerated by the upwelling and circulation of bottom water and organic material having a high B.O.D.

EXPERIMENT WITH SUSPENDED AIR CONDUCTOR

It seemed possible that the method of artificial circulation employed in 1958–59 might be used successfully if certain modifications were made to increase the rate of circulation. These modifications included (1) an earlier start—either before or immediately after ice formed; (2) installing the air conductor closer to the ice cover; and (3) increasing the number of openings in the line. If, for example, the line lay 5 ft. below the surface instead of at a greater depth, only this upper stratum would be circulated and presumably aerated, thereby creating a safety zone for fish. The denser, warmer water beneath might not be affected because of the temperature gradient which presumably would be established at approximately the 5-ft. level. Near-normal winter temperatures would prevail near the bottom, thereby eliminating an abnormal thermal condition that might be deleterious to bottom fauna.

In Loon Lake in 1958–59, when the air conductor lay at a maximum depth of 10 ft., about 95 percent (72.4 a.-ft.) of the total volume of water in the lake was being circulated. These observations suggested that about 71 percent (54.4 a.-ft.) of the total volume would be circulated if the line were suspended at the 5-ft. level. It seemed probable that the velocity of the lateral current would be increased and, of course, less bottom area would be exposed to the circulating water, thereby lessening the oxygen demand.

In 1959–60, the air conductor in Loon Lake was held at a depth of 5 ft. by wooden floats. Circulation was not begun until December 8, 1959, although an ice cover had formed on November 15. Very little snow had fallen and the weather was warm most of the first week of December. Oxygen values averaged 10.3 p.p.m. at a depth of 4 ft. and 4.4 p.p.m. at 10 ft. (averages for two stations).

Despite the changes in procedure, a downward trend in oxygen developed immediately in the zone of circulation both in open water and beneath the ice 200 ft. away—almost identical to that which occurred in Loon Lake in 1958–59 (Table 2). Below the 5-ft. level the decline of oxygen was more rapid. Values of 0.5 p.p.m. or less were first recorded at a depth of 12 ft. on January 13; 8 ft. on February 3; 7 ft. on February 22; and 6 ft. on March 3. On March 2, with oxygen values standing at 1.2 p.p.m. just below the ice, the number of holes in the air conductor was doubled, but this too failed to halt the decline. On March 14, when the oxygen was reduced to 0.5 p.p.m. at the 4-ft. depth both in open water and as far away as 400 ft., the air compressors were shut off. Not until March 28, following a 24-hr. warming period, did the oxygen level start to rise.

Schmitz and Hasler (1958) described rates of treatment in 2 successive years for a Wisconsin lake. At daily rates of about 1/17 and 1/10 cu. ft. of air per minute per acre-foot, dissolved oxygen was maintained at about 2 and 7 p.p.m., respectively. These rates closely approximate the rates used in Loon Lake (1/16 in 1958–59 and 1/12 in 1959–60).

WINTERKILLS OF FISH IN LOON LAKE

Winterkills of fish were observed in Loon Lake in both winters. In 1958–59, although the dissolved oxygen under the ice had been around 1.0 p.p.m. since February 23, it was not until March 18 that a few distressed bluegills (*Lepomis macrochirus*) and pumpkinseeds (*Lepomis gibbosus*) were observed. These fish were crowded into holes in the ice through which water samples had been taken. Dead fish of these species also were found in wire traps on March 19, 20, and 23, after which no more fish were caught. Probably a heavy fish kill was avoided when a thaw began on March

19 and the oxygen level started to rise. A search of the shoreline following the breakup of the ice disclosed 29 dead fish.

A moderately heavy winterkill of fish (mostly bluegills) occurred again in the winter of 1959–60. When the oxygen had declined to 1.0 p.p.m. or less (at a depth of 2 ft.) on March 9, small bluegills again congregated in an open hole in the ice. Oxygen values of less than 1.0 p.p.m. were obtained between March 9 and 27 (the lowest recorded value was 0.7 p.p.m. on March 14) and, following the dispersal of the ice cover, 461 fish at least 3 in. long were counted. Of these, 94 percent were bluegills. A number of small sunfishes, bullheads (*Ictalurus* spp.), and frogs were seen on the bottom but no counts were attempted.

There is a strong possibility that the air-induced circulation helped cause the winterkills instead of preventing them. There was a rapid decline in oxygen after the air conductor (and water circulation) was started. It seems reasonable to assume that if this decline had not been accelerated there might have been an adequate supply of oxygen to sustain the fish population until the spring thaws occurred. Although Loon Lake has a past history of winterkills, they have not been observed in successive years.

SUMMARY

The feasibility of preventing winterkills of fish by means of circulating water with compressed air was tested in two Michigan lakes at the Rifle River Fisheries Research Station in the winters of 1957–58, 1958–59, and 1959–60.

In 1957–58, an unsuccessful attempt was made late in February to recharge the upper end of Spring Lake with oxygen after the supply was nearly exhausted. Holes were opened up overnight in ice as much as 15 in. in thickness and an open channel, 10 to 21 ft. wide, was maintained.

In 1958–59, operations were started in Loon Lake on December 30, 1958, and a rapid decline in oxygen occurred, halted only by a thaw late in March. Oxygen values as low as 0.4 p.p.m. 2 ft. below the ice were detected. A small winterkill occurred. Temperatures of the water and bottom mud were lowered. A temperature gradient was established in the lake at about the level of the air conductor (8 to 10 ft. deep) above which was a nearly uniform temperature zone of approximately 32° to 34°F.

In 1959–60, a similar downward trend in oxygen developed in Loon Lake despite an earlier start (December 8, 1959) and the suspension of the air conductor at a depth of 5 ft. Doubling the number of apertures failed to halt the oxygen decline. A moderately heavy kill of fish (mostly bluegills) occurred.

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REPORT OF ATTEMPTS TO ESTABLISH JAPANESE QUAIL IN ILLINOIS

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Since about 1955, a renewed effort has been made to introduce and establish an exotic quail of the genus *Coturnix* as a game bird in the continental United States. The quail with which state game agencies are experimenting is *presumably* a migratory Asiatic race, *Coturnix coturnix japonica*, commonly known as the Japanese quail. Members of this race have been domesticated in Japan for several centuries (Taka-Tsukasa, 1935:234). The present paper reports the results of some releases of *Coturnix c. japonica* in east-central Illinois during 1957 and 1958 and speculates as to why these quail released in Illinois and other midwestern states have not established themselves.

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History

The genus *Coturnix* is native to Eurasia, Australia, Africa, and some islands of the eastern hemisphere. Some races of this genus are migratory, while other races are permanent residents on such islands as the Azores, Cape Verde, Madeira, and Canary. *Coturnix c. japonica*, a migratory race, breeds on the Japanese islands and Sakhalin, and winters in China, Siam, Indochina, Formosa, and Hainan (Peters, 1934: 92).

Early attempts were made to establish *Coturnix coturnix* in the eastern United States and southeastern Canada during the period from 1875 to 1880; many of these imported quail were obtained from Italy (Phillips, 1928:38). There were reports of breeding by these quail during the season following release, but after the fall dispersal there were no return movements.

Coturnix c. japonica was introduced in the state of Washington prior to 1904 and again in 1923, and also in California during the period 1900–04; these quail were imported from northern China (Phillips, 1928: 39; Taylor, 1923). However, the quail did not become established in either Washington or California.

As a result of the failures to establish these exotic quail as an American game bird, McAtee (1929:19) classed *Coturnix coturnix* among species "considered undesirable" for introduction into the United States.

However, *Coturnix c. japonica* was successfully introduced into the Hawaiian Islands in 1921 and has since become an abundant game bird (Schwartz and Schwartz, 1949:91). There are no indications of seasonal migrations of *Coturnix c. japonica* in Hawaii.

In its native breeding range in Japan, *Coturnix c. japonica* inhabits "grassy flatlands, cultivated or abandoned fields, pastures, and dry marshes" (Austin and Kuroda, 1953:388). Speaking of *Coturnix coturnix* in the British Isles, Moreau (1951) states, "Most of the modern British records of Quail which mention the habitat cite corn and each of my own personal records has been in wheat, oats or barley." In Hawaii, the introduced *Coturnix c. japonica* occupies diversified farming areas and pastures on relatively level and rich soil; the best quail populations are found at altitudes of less than 7,000 ft. and where an-

nual rainfall is 60 in. or less (Schwartz and Schwartz, 1949:91). However, Schwartz and Schwartz (1949:95) also state that "Regardless of the various land uses within the range, the Japanese quail favors grass as cover."

Seeds and animal matter provide the staple diet of *Coturnix c. japonica* (Schwartz and Schwartz, 1949:94; Stanford, 1957).

In 1955, *Coturnix c. japonica* was introduced into Missouri, with hopes of establishing a game bird that might possibly absorb some of the increase in hunting pressure foreseen for future years. Stanford (1957) presents a detailed account of Missouri's experimentation with the quail. Missouri obtained its breeding stock of *Coturnix c. japonica* from an importer and breeder in California; the quail were the 1954 progeny of birds imported directly from Japan in 1953 (Stanford, 1957). Illinois obtained its breeding stock of *Coturnix c. japonica* from Missouri. The quail used in the Illinois releases were propagated at the Illinois State Game Farm, Mt. Vernon.

EXPERIMENTAL RELEASES

The releases of *Coturnix c. japonica*, hereafter referred to as Japanese quail, discussed in this paper were made on a 37-square-mile study area near Sibley, in the intensively farmed cash-grain region of east-central Illinois. About 95 percent of the area is cultivated; corn and soybeans annually occupy more than 50 percent of the total land area. The mean annual temperature and precipitation for this area are 51°F. and 33 in., respectively. The study area supports one of the highest populations of pheasants (*Phasianus colchicus*) in Illinois but contains only an occasional covey of bobwhite quail (*Colinus virginianus*). These investigations of Japanese quail were carried out coincidentally with investigations of pheasants. All of the released quail were banded with numbered, aluminum, butt-end leg bands.

Spring release, 1957.—Five hundred quail (343 cocks and 157 hens) less than 1 year old were liberated as a group near the center of the study area on April 29, 1957. The quail were released in a 140-a. hayfield containing red clover, alfalfa, sweet clover, and timothy. The hayfield was surrounded by corn stubble, soybean stubble, and plowed land. The nearest brushy cover was along a drainage ditch about 300 yd. from the release site. About 40 a. of the hayfield were plowed on May 9, but the remainder was left undisturbed throughout the summer and fall.

The quail were in excellent condition when released and were capable of good flight. Within minutes after release, the quail began to feed industriously on the hayfield vegetation, particularly red clover leaves. Courtship displays and copulation attempts were observed frequently among the liberated quail. The cocks "sang" repeatedly until after sunset. Some birds had dispersed about 400 yd. by sunset, but most remained near the release site.

Within a few hours the liberated quail had attracted a concentration of predatory birds, including marsh hawks (*Circus cyaneus*), rough-legged hawks (*Buteo lagopus*), and crows (*Corvus brachyrhynchos*). Marsh hawks, the most numerous and adept avian predators, were observed killing several quail. Crows harassed the quail considerably but were observed to kill only one bird. Several rough-legged hawks hunted in the release area and harassed the quail, but quail were not observed to have been captured by them. On May 6, a week after the quail were liberated, hawks and crows had dispersed from the area of release. Although it was impossible to ascertain the precise magnitude of mortality caused by predatory birds, it was evident that many quail had been killed.

Six nests of Japanese quail, all of which were established in tame hayfields, were located during the spring and summer of 1957. All nests were found within 1,000 yd. of the release site. Four nests were located in the hayfield where the quail were released; this hayfield of approximately 100 a. was intensively searched for both pheasant and quail nests during late May and early June. The fence rows and roadsides bordering the release area were also

searched for nests, but none were found. However, it is probable that some nests were established in cover beyond the boundary of the area that was searched.

All of the nests were in relatively dense cover and, with the exception of one, were well constructed. The nests were of the open-bowl type, with the outside diameter varying between 6 and 7 in. The nests were situated in shallow scrapes and were lined with a 2-in. mat composed of oat straw and legume stems and leaves.

Only one of the six nests hatched, although two other clutches had been incubated prior to their disruption. Two of the incubated clutches had 10 eggs; the number of eggs in the other clutch could not be determined. All of the nests were established during late May and early June.

A nest containing three pheasant and two Japanese quail eggs was found after it had been disrupted by mammalian predators. This nest was typical of construction by pheasants, which suggested probable parasitism of a pheasant by a Japanese quail.

A single Japanese quail brood, a hen and three chicks, was observed in a hayfield near the release site on June 7. Two quail were captured by the night-lighting technique (Labisky, 1959) during the fall of 1957. Neither of these birds, trapped about 1,000 yd. from the release site, carried leg bands, a fact which indicated that they were hatched on the area, were possible migrants, or had lost their leg bands. The first possibility seems most likely.

The quail that remained in the vicinity throughout the summer were never observed more than a mile from the release site. Although single birds and pairs were frequently flushed near the release site until mid-September, it seems probable that many of the liberated quail dispersed from the release area and possibly from Illinois. "Singing" by quail was common until late July but occurred only occasionally thereafter. The last birds seen in the vicinity of the release area, a pair and two single birds, were flushed during nighttime from an oats stubble field on November 5. Apparently no quail wintered near the release area, and no return migrants were observed the following spring.

Bands were recovered from 17 of the 500 quail originally released, and these were recovered from birds which either died or were killed near the release site.

Fall release, 1957.—Four hundred and ninety-eight quail of unknown sex, approximately 10 weeks of age, were liberated as a group on September 5, 1957, about 3 miles southwest of the site of the spring release. The weather was warm and clear for the release. The birds were liberated in a 25-a. oats stubble field which contained a dense growth of red clover and weeds; the field was bounded by soybeans, bluegrass (grazed), roadside, and a multiflora rose hedge. The oats stubble field was left undisturbed throughout fall and winter.

The released quail were in fair physical condition and were capable of moderate to strong flight. Their behavior upon release was similar to that of the birds released in the spring. They did not attract an unusual number of predatory birds.

Dispersal of the quail from the release site was rapid, and, by September 15, most had traveled at least 400 yd. Only a few birds were observed after September 20. A pair, the last quail to be sighted in the vicinity of the release area, was flushed on November 11. No quail were observed near the release site during the following winter or spring.

Not a single dead quail was found near the release site even though repeated searches for dead birds were made. Only two band recoveries from the quail released on September 5, 1957, have been reported. One quail was found dead 11 mi. east of Toledo, Ohio, on December 21, 1957, about 365 miles east-northeast of the release site. The other band was recovered from a quail shot on December 8, 1957, near Dieterich, Illinois, about 110 mi. south of the release site.

Spring release, 1958.—Five hundred quail (250 cocks and 250 hens) were released as a group near the center of the study area on April 23, 1958. The quail were liberated in a 20-a. red clover field which was

bounded by corn stubble, oats seeding, plowed land, and a drainage ditch. The weather conditions, however, were adverse: cold, rainy weather preceded the release and persisted for several days. The quail, all less than 1 year old, were in excellent condition and were capable of strong flight; many flew distances of 200 yd. when released. They began to feed within minutes after being liberated; "singing," courtship displays, and copulatory attempts were also common.

Intensive searching of the release area on April 25, 28, 29, and 30, yielded 64 dead Japanese quail. The factors causing death of these birds were not evident, but it seemed probable that these hatchery-reared quail were unable to adjust to the adverse weather conditions. Nineteen bands were recovered on May 2 at the site of a den of red foxes (*Vulpes fulva*) located about ½ mi. from the release site. No other band recoveries have been reported. Predatory birds did not congregate in the release area.

Five Japanese quail were flushed in 8 man-hours of walking in the area surrounding the release site on April 30. These were the last birds observed, even though searches of the release area and surrounding land were continued for several days. Evidently, the quail surviving the release dispersed from the area, but there are no band recoveries to verify this premise.

DISCUSSION

The limited attempts to establish Japanese quail as either a resident or migratory game bird in Illinois were unsuccessful. Several other midwestern states also have been unable to establish self-maintaining populations of Japanese quail, although some of these states have released many thousands of quail (personal communications). In view of possible future attempts to introduce Japanese quail as a game bird in the United States, some speculations can be suggested as to why the bird has apparently failed to succeed.

The source of the original stock is one factor that must be considered as a possible explanation for the recent failure of the quail to become established in Illinois and other midwestern states. Japanese quail have been raised in captivity for centuries in Japan (Taka-Tsukasa, 1935:234) and have become the source of a commercial egg industry (Austin and Kuroda, 1953: 390). Although the original stock obtained by Missouri were the 1954 progeny of birds imported from Japan in 1953 (Stanford, 1957), it is possible that the stock originated from domesticated quail. If this is true, and because Illinois and some other states obtained their breeding stock from the Missouri stock, the failure of the birds to become established may be associated with a loss of "wildness" and vigor due to domestication. Such a change in the behavioral and physiological complex of Japanese quail, resulting from domestication, might not only explain the failure of the birds to succeed in the wild but also might provide some explanation for radical dispersions as well as other aspects of unusual ecology observed among the liberated quail.

Another factor to be considered is that of reproduction. Of the two releases of 500 Japanese quail in east-central Illinois during the springs of 1957 and 1958, only the quail from the 1957 release contributed reproductively (at least in the area of release). Limited evidence of nesting by liberated Japanese quail has also been reported in Missouri (Stanford, 1957). It seems most improbable that the reproductive effort exhibited by Japanese quail in the wild, at least of those released in Illinois, would be sufficient to maintain a population, even at low levels. However, it is rather doubtful that the quail's innate reproductive ability would be a factor limiting its successful establishment if the bird were behaviorally and physiologically adapted to its new environment.

Some consideration must also be given to a comparison of climate in the quail's native and introduced range. In its native range in the Japanese islands, the Japanese quail occupies a breeding range of 25° latitude, between 30° and 55° north. The comparable breeding range in North America would extend from southern Canada,

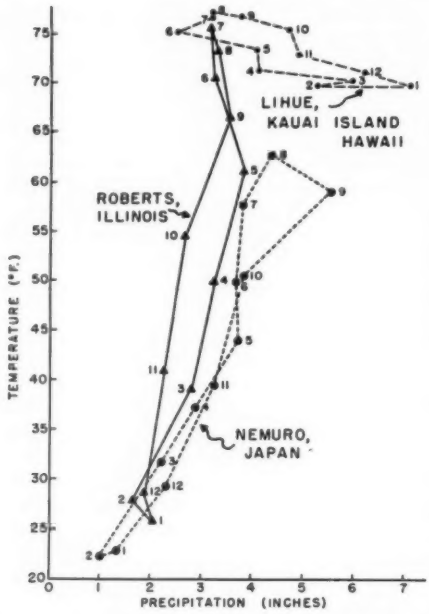

FIG. 1. Temperature-precipitation climatographs. The numbers 1 to 12 designate the months from January to December, respectively. Sources of data: Roberts, Illinois (L. 40°40′ N.), "long term means" (U. S. Dept. Com., Weather Bur., 1956); Nemuro, Hokkaido Is., Japan (L. 43°20′ N.), means from 1884 to 1920, (Smithsonian Inst. 1927); and Lihue, Kauai Is., Hawaii (L. 21°59′ N.), means from 1911 to 1950 (U. S. Dept. Com., Weather Bur., 1959).

south to the extreme southern areas of the United States. Climatographs for Roberts, Illinois (Lat. 40°40′ N.), which is located about 10 mi. northeast of the release areas in Illinois, and Nemuro, Japan (Lat. 43° 20′ N.), reveal that the Illinois climate is warmer and dryer during the spring and summer than is the climate within the breeding range of quail on the Japanese island of Hokkaido, Fig. 1. A further comparison of climatographs shows that Lihue, Kauai Island, Hawaii (Lat. 21°50′ N.), has a warmer and wetter climate during the breeding season than either Roberts, Illinois, or Nemuro, Japan; yet the quail was successfully introduced into Hawaii in 1921 and has since become an abundant non-migratory bird (Schwartz and Schwartz, 1949:91). Perhaps the oceanic influence on climate, characteristic of Japan and Hawaii and lacking in Illinois, is a factor which partially regulates the reproductive complex of this particular race of quail.

In its native range, the wintering area of the Japanese quail covers about 20° latitude, betwen 10° and 30° north. Comparable wintering range for the North American transplants would extend from extreme southern United States south into Mexico and Central America. Information regarding quail which may have migrated to this latitude is lacking.

Apparently the Japanese quail have failed to establish defined migratory routes in North America; the dispersal of released birds seems to be to all points of the compass. Band recoveries from liberated Japanese quail indicate some tendency toward southerly movements in late summer and fall (Stanford, 1957). To my knowledge, there have been no verified reports of the northward return of quail following late summer and fall dispersal.

The lack of refined data on nearly all aspects of ecology of the Japanese quail released in Illinois, and perhaps in most other midwestern states, precludes sound conclusions as to the failure of the birds to become established as either migratory or resident game birds. Consequently, the feasibility of introducing the bird to occupy so-called "unoccupied" habitat niches remains highly questionable.

SUMMARY

Three groups of 500 Japanese quail (*Coturnix coturnix japonica*) were liberated in an intensively cultivated area of east-central Illinois during 1957 and 1958. Of the two releases made in the springs of 1957 and 1958, only the quail from the 1957 release are known to have reproduced, and this reproductive effort was at a very low level. Many quail dispersed from the area shortly after being released, but, because of few band recoveries, the directions and distances of the dispersal movements could not be determined. No Japanese quail win-

tered in the areas of release, and there was no known spring return of migrants following their late summer or fall dispersal. Some factors, which offer possible explanations for the inability of the imported Japanese quail to become an established game bird in Illinois and other midwestern states, are discussed.

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THE CARE AND MANAGEMENT OF WILD UNGULATES FOR EXPERIMENTAL PURPOSES

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The evolution of sound procedures for the management of wild ungulates must be predicated upon a detailed quantitative knowledge of their normal growth and development under conditions of known nutrient intake. The physical limitations placed on quantitative measurements in the field have prompted the establishment of a unit of such animals held captive under essentially laboratory conditions. The care and management procedures that have been evolved over a 10-yr. period appear to be worthy of record for two reasons. Firstly, such a record can provide a background of reference for more detailed studies to be reported on the bioenergetics and growth of these animals. Secondly, the information recorded may be of value to others working or contemplating studies in this area.

The facilities and methods to be described have been evolved in the course of studies with the deer. The suitability of these facilities for other species such as moose and bighorn sheep has been demonstrated and suggests that other wild ungulates can be handled and studied with equal facility by use of these procedures.

GENERAL FEATURES

Experience gained through the use of a series of temporary structures led to the design and construction of the unit shown in Figs. 1 and 2. It should be pointed out that certain of the design features shown

FIG. 1. Aerial view of wildlife unit.

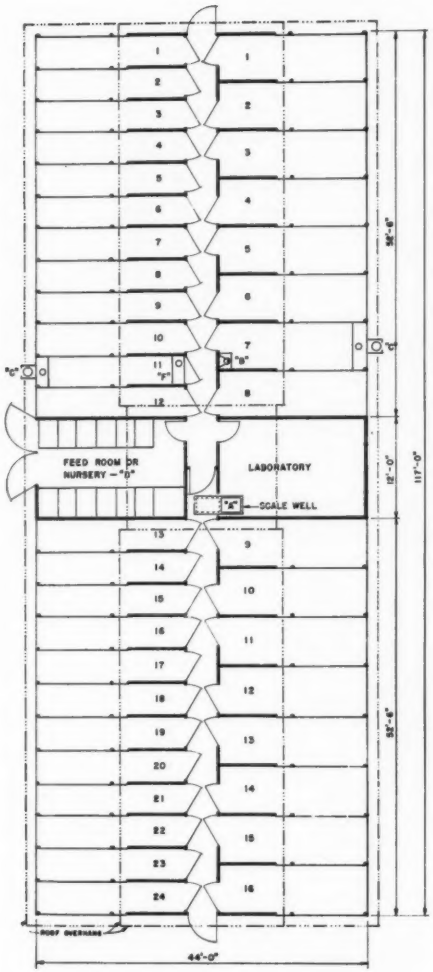
were dictated by the climatic situation in our area. For example, the entire unit including exercise runs is covered to avoid accumulation of excessive moisture from natural precipitation. The roof and wall design provides for more than the amount of ventilation normally given for enclosed animal units. This added ventilation has been found to effectively carry away excess surface moisture.

A variety of standard pen floor materials has been used with deer and other wild species. On the basis of these evaluations it has been found that a 6-in. layer of rock aggregate (1 in. diameter) laid over a well-drained soil provides the most satisfactory floor. If such a soil type is not readily available, it can be simulated by use of a deeper layer of rock aggregate and suitable tile drains.

No problems have been encountered with endoparasites using this type of floor even though animals of various ages and from various natural habitats have been housed continuously for a period greater than 5 yr.

The use of ¼-in. plywood for pen sides, gates or other sheeted surfaces has proved to be very satisfactory. It combines reasonable strength with a smooth surface that facilitates maintenance. The relatively low cost of plywood permits replacement when severely damaged upon occasion by a male animal during rut. Where no roughage is fed it is common to find that animals will eat the hair off those in adjoining pens. Under such circumstances, 4- × 8-ft. sheets of ¼-in. plywood can be attached to the pen rails to prevent contact between adjacent animals.

All interior and exterior surfaces are coated with a good quality of white oil paint. This treatment has aided in the preservation of the construction materials and greatly facilitated washing and cleaning procedures.



PLAN 1

FIG. 2. Plan view of wildlife unit.

COSTS

The unit described was built and equipped at a cost of $2.50/sq. ft. When all units are fully occupied by weaned animals (48), the feed cost is about $5.00 per day and the labor cost is equivalent to 4 man-hours per day. This amount of labor provides for daily recording of feed and water intake and pen cleaning as well as maintenance. It does not include weighing of the animals and the various procedures of animal care such as hoof trimming and external parasite control measures.

FEEDING AND WATERING DEVICES

The usual methods of feeding domestic animals are not adequate for the quantitative measurement of feed intake. The feeding device shown in Fig. 3 (see B, Fig. 2) permits accurate measurement of feed consumption. The device has the added feature that feed can be provided by the animal attendant from outside the pen, a distinct advantage when males are in rut.

To facilitate the handling and weighing of feed, a monorail track (sliding door track) is affixed to the roof of the central service passageway through the unit. A small crate with two shelves is suspended from the monorail track to carry the day's supply of feed. A dial scale is hung from

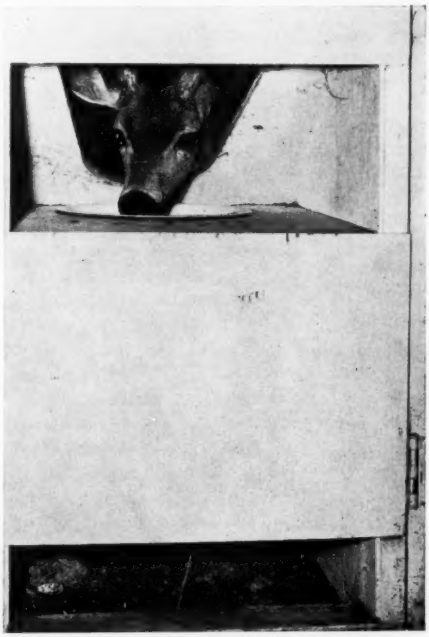


FIG. 3. View of feeding device from service passageway.

FIG. 4. Feed carrier and feed scale.

the center support of the crate for convenience in weighing the feed. The arrangement of the equipment is shown in Fig. 4.

The water fountain shown in Figs. 5 and 6 (see C, Fig. 2) is satisfactory under our climatic conditions. It insures a steady supply of fresh water which cannot be damaged by males in rut, and has the additional advantage that water intake can be measured by calibrating the water storage bottle. Where low winter temperatures are likely to cause freezing, this difficulty can readily be overcome by suspending an infrared heat lamp over the water storage bottle. This watering system lends itself to the per orum administration of medicaments when such are required.

ANIMAL WEIGHING

A depression (see A, Fig. 2) 30 in. wide and 8 in. deep is constructed at the midpoint of the central service alleyway to accommodate a suitable scale (Fairbanks Morse Model 5264-Serial G401965). This depression extends into the laboratory in such a way that the entire scale can be rolled into the laboratory when not in use. When animals are to be weighed, the scale platform is rolled into the portion of the depression that extends into the alleyway. The tare beam and dial of the scale remain in the laboratory to permit recording of the animal weight without disturbance to the animal. A plywood platform is placed over the scale platform to provide adequate standing areas for the animal while the weight is being taken. The animal to be weighed is driven from its pen down the central service passageway to the scale enclosure. The arrangement is shown in Fig. 7 (see A, Fig. 2).

The doorways closing the animal pens are 4 ft. in width so that they can exactly close the central service passageway when they are opened. This greatly facilitates

FIG. 5. Drinking bowl in animal pen.

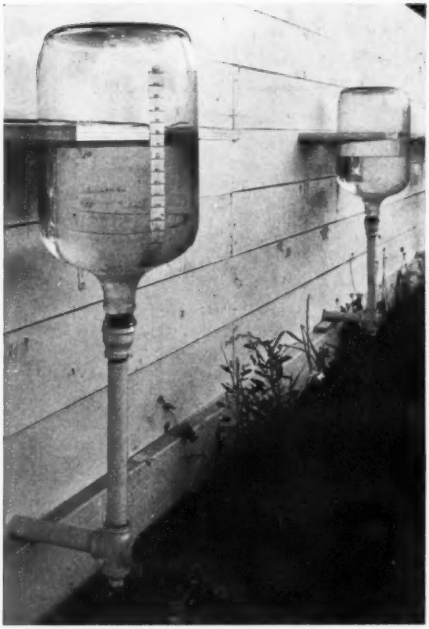


FIG. 6. Calibrated water reservoir supported on outside wall of animal unit.

the movement of animals to and from the weighing area. A sheet of ¼-in. plywood 4 ft. × 6 ft. with two attached handholds is used as a shield to move the animals from the pens, down the alleyway and onto the scale. This shield permits the animal technician to handle all but the most refractory animals in complete safety and with a minimum of danger to the animal. We have had animals that we were unable to weigh without tranquilization during the height of the rut. Males in velvet can safely be moved without damage to the developing antlers. Using this arrangement of pens, shield and scale, it is possible for three technicians to weigh 40 animals in less than 1 hr.

FAWN NURSERY

For the rearing of new-born fawns, the facilities shown in Fig. 8 (see D, Fig. 2) have been satisfactory. Again the extensive use of ¼-in. plywood suitably coated with a good grade of oil paint has been convenient. In this case a concrete floor covered with a 1-in. layer of shavings overlaid with a generous supply of clean straw or hay has proven to be satisfactory. The feeding device is illustrated in Fig. 8.

SANITATION AND CLEANING

Fawn Nursery

The marked susceptibility of young fawns, particularly those that may not have had full access to their dam's colostrum, to various respiratory and enteric infectious agents, necessitates the application of meticulous sanitation techniques. Each fawn on arrival at the nursery is given 150,000 i.u. Procaine Penicillin G, 50,000 i.u. Penicillin G Potassium and 250 mg. of Streptomycin Sulphate as a 1 cc. intramuscular injection. In addition, the hair is clipped from the region of the buttocks to facilitate daily washing of this area with a dilute hypochlorite solution (200 p.p.m.). Feed and

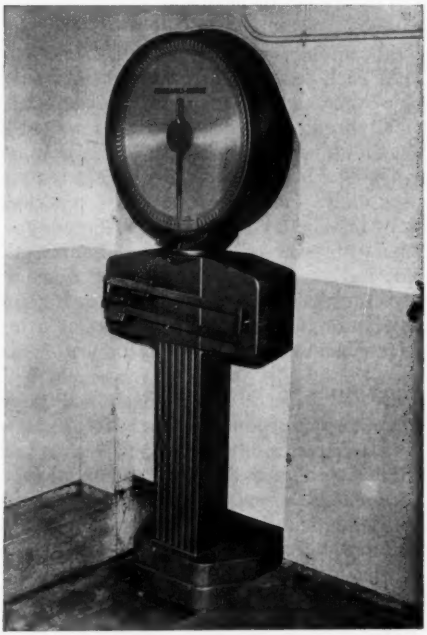


FIG. 7. View of scale in operating position.

FIG. 8. A nursery pen showing feeding and watering devices.

fluid containers must be washed thoroughly after each feeding and rinsed with a suitable germicide. A sodium hypochlorite (400 p.p.m.) rinse is satisfactory and economical.

The bedding should be removed from the pens daily. When fresh bedding is added, ¼ oz. of methoxychlor is distributed uniformly through the bedding. This insecticide has a relatively low toxicity for mammals and has provided excellent control of the house fly and other objectionable insects when new fawns are introduced.

Adult Animals

Sanitary procedures with adult animals do not differ from those normally observed with research colonies of domestic animals. Pens should be steam cleaned with a suitable detergent four times a year or more frequently if required. The floor of the pen lends itself to deep (10 in.) cultivation with a mechanical tiller. This serves to maintain porosity for drainage and to encourage aerobic decomposition of animal wastes. Such cultivation is undertaken on a rotational basis so that each pen is turned over about once in 2 mo. Feed pans are washed weekly. During the summer months methoxychlor is sprinkled in the bedding.

Under this regimen we have not encountered ectoparasite infestation in any of the pen-raised animals.

BREEDING

Our experience has been that successful breeding is most difficult where large numbers of bucks are kept penned separately but in contact in the same unit. The mutual stimulation leads to a chronic aggressive behavior which is directed toward the doe as well. Breeding under observation was accomplished without trouble where two or three bucks, housed apart from the rest and each other, were used.

A few minutes' observation when the doe is admitted to the buck's pen will indicate whether mating is likely. It usually occurs within ½ hr. after placing the animals to-

gether. Under no circumstances were the deer left together unattended.

With black-tailed deer, 18-mo.-old bucks were the most successful sires; older animals were slower to mate and inclined to be more aggressive toward the doe. Rams and ewes of bighorn could usually be left together during the breeding period without hazard to the ewe.

DIET AND FEEDING

Fawns

Several special milk formulations have been used with varying degrees of success (Murphy, A. 1960. J. Wildl. Mgmt., 24:439). Experience has shown that ordinary evaporated milk is completely satisfactory when supplemented with copper, iron, and magnesium. One cc. of solution containing ferric citrate, 13 g. per liter; copper sulphate, 0.60 g. per liter; and magnesium chloride, 50 g. per liter is added to one feeding of milk for each animal each day. Fawns born in the unit are allowed to feed on the mother until weaning weight is reached, when they are removed from the doe's pen. When fawns are received from the wild, they are offered a mixture of one part of evaporated milk and one part of warm water in a 12-qt. pail. The fawns learn to drink from the pail after a few feedings. This feeding procedure is preferred to bottle feeding because sanitary control of feeding containers can be maintained more readily. In addition, the ultimate weaning of fawns from a milk regimen to solid feed can be achieved with greater ease. Each fawn is given a 20-mg. tablet of a tetracycline antibiotic (Aureomycin or Terramycin) each day to aid in the control of bacterial scours. Table 1 presents a typical feeding schedule used successfully with black-tailed fawns. It is of the greatest importance to feed small amounts frequently. We have had consistently better results in terms of growth and absence of enteric disturbances by increasing the feedings from 4 times daily to 6 times daily. A still further increase in frequency of feeding would probably permit even faster growth, but complicates the management regimen.

TABLE 1.—MILK FEEDING SCHEDULE FOR FAWNS

Approx. Age (days)	Body[1] Weight (lb.)	Evaporated Milk (oz. per day)	Water (oz. per day)	Digestible[2] Calories
11	7	16.75	16.0	670
	8	18.00	15.0	720
	9	19.25	12.0	770
21	10	20.50	9.0	820
	11	21.75	6.0	870
	12	23.00	3.0	920
	13	24.25	0.0	970
33	14	25.50	–	1,020
	15	26.75	–	1,070
	16	28.00	–	1,120
43	17	29.25	–	1,170

[1] Milk (oz. per day) = 1.25 × body weight (lb.) + 8.
[2] Digestible Calories per day = 50 × body weight (lb.) + 320.

The feeding schedule presented suggests a simple arithmetic relation between body weight and caloric requirement. This arises because the body weight range covered is relatively narrow. In actual fact the caloric requirement is undoubtedly curvilinear. That is, the caloric requirement per unit mass declines as the animal gains in body weight.

Weaning of fawns to a dry feed is carried out over a relatively short time interval. As a general rule the animals have been found to be amenable to weaning when their body weight has reached 12 to 15 lb. or at an age of about 6 weeks.

The ration formulation presented in Table 2 has permitted early weaning of fawns from a milk regimen and has yielded near maximum growth rates. This formulation is fed as a ¼-in. cylindrical pellet ⅜ in. long.

When fawns have reached a body weight of approximately 15 lb., the daily allotment of milk is gradually reduced to 0 over a 7-day period. During this time the above pelleted ration plus a clean container of water is kept before the animals at all times. In the majority of cases, this ration permits weaning to dry food in 7 days or less. Growth rate is only interrupted to a slight degree. Experience has shown that within a short period (usually about 1 week) the slight interruption in growth is immediately

TABLE 2.—FORMULATION FOR UNIVERSITY OF BRITISH COLUMBIA DEER WEANING RATION NO. 36-S-60

Constituent	Pounds per Ton	Pounds per 100
Ground No. 5 feed wheat	660	33.0
Ground oat groats	260	13.0
Ground wheat bran	200	10.0
Ground yellow corn	200	10.0
Fish meal (70%) herring	200	10.0
Soybean meal (50%)	100	5.0
Skim milk powder (spray)	200	10.0
Dehydrated grass	100	5.0
Dicalcium phosphate	10	0.5
Iodized salt	15	0.75
Stabilized animal fat	50	2.5
Vitamin pre-mix	5	0.25
	2,000	100.00

compensated for by an increased rate. We have never been able to feed with sufficient frequency on a milk regimen to permit fawns to grow at the rate they do on the best doe mothers. However, with this weaning diet, compensation occurs during the post-weaning period to an extent sufficient to achieve body weights equal to or in excess of those recorded for doe-raised fawns.

Adults

Fawns are considered as adults for feeding purposes by mid-November at an age of 5 mo. At this time they are gradually switched (7 days) to the ration formulation shown in Table 3. French, C.E., *et al.*, (1956. J. Wildl. Mgmt., 20:221–232) have suggested other experimental diet formulations.

The ration is formulated to the specifications given in Table 3 by a commercial feed manufacturer. It is delivered in bulk as ¼-in. cylindrical pellets, ¼ in. long. We have found it convenient to store the pellets in a standard cylindrical steel storage tower, 7 ft. in diameter, of a type in general use in agriculture. The pellets are fed in a dish-pan 15 in. in diameter and 5 in. deep (see Fig. 3). A weighed amount of this ration in excess of anticipated requirement is placed in front of each animal each day. On the following day the weight of any feed not consumed is deducted from the original weight of feed offered to obtain the daily feed consumption. Inasmuch as our experiments have required strict control of nutrient energy intake, dry or green roughage has not been offered. Animals have been carried for periods of 4 yr. on this roughage-free regimen. Water is available at all times and daily consumption is recorded from the graduated reservoir shown in Fig. 6.

The facilities, rations, and procedures outlined above have been evolved over a period of 10 yr. Both sexes of the various subspecies of the black-tailed deer have been reared and maintained in excellent condition from birth to an age of 6 yr. White-tailed deer, bighorn sheep, and moose to yearling age, have been reared with equal facility.

The penning and handling methods described have permitted the collection of detailed data on the growth rate and feed requirements of the deer. The results of these studies will be reported in subsequent communications.

TABLE 3.—UNIVERSITY OF BRITISH COLUMBIA RATION NO. 36-57 FOR ADULT DEER

Constituent	Pounds per Ton	Pounds per 100
Ground yellow corn	600	30.00
Ground No. 5 feed wheat	250	12.50
Ground wheat bran	275	13.75
Molasses (cane)	150	7.50
Ground beet pulp	200	10.00
Dehydrated grass meal	200	10.00
Soybean meal (50%)	175	8.75
Fish meal (70%) herring	110	5.50
Steamed bone meal	20	1.00
Iodized salt	20	1.00
	2,000	100.00

IMMOBILIZATION OF FREE-RANGING EAST AFRICAN UNGULATES WITH SUCCINYLCHOLINE CHLORIDE

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Immobilization of wild animals in the field has been developed as an important research tool in wildlife studies in progress in Kenya and Tanganyika. In the Tanganyika Game Department work, field immobilization has two main functions: to facilitate the marking of animals for tracing movements and social behavior; and to capture and translocate immobilized and subsequently tranquilized animals from areas of overpopulation or human settlement to more suitable habitats. In the Wildlife Research Project field immobilization has additional applications in weight determinations and blood and parasite collections from living wild animals so that growth rates and condition changes may be traced subsequently, and in capture and translocation of animals to be kept in paddocks as experimental herds. Successful application of this technique has yielded invaluable data to both studies.

No previous data were available on immobilization drugs and techniques that applied to the animals and field conditions encountered in the present studies. Therefore, considerable time has been devoted to development of field immobilization as an effective research tool. The present work has extended over a period of 16 months, starting in July 1959. During this period several immobilizing drugs were used (Lamprey, 1960; Talbot, 1960a, 1960b, 1960c), but the one with which most work has been done to date, both in experimentation and in field application, is succinylcholine chloride.

The purpose of this paper is to present our findings to date on the use of succinylcholine chloride in field immobilization of seven species of East African ungulates in the acacia savannah of Kenya and Tanganyika.

The history of the development of succinylcholine chloride and its use in veterinary practice with domestic livestock has been summarized by Pistey and Wright (1960). The drug has been applied to various captive wild animals in zoological gardens (Pistey and Wright, 1959, 1960; Wright, 1959). In North America, succinylcholine chloride has been used successfully to immobilize wild grizzly bear (Craighead, *et al.*, 1960), black bear (Black, *et al.*, 1959), and caribou (Peters, 1958). In East Africa, this drug has been used with varying degrees of success. Forty-six Uganda kob were immobilized with no fatalities (Buechner, *et al.*, 1960a). Evidence from Uganda based on immobilization of from one to seven animals of each species indicates that succinylcholine chloride may be an effective immobilizing agent for Jackson's hartebeest, Grevy's zebra, and waterbuck. The drug appears much less satisfactory (because of an extremely narrow range of effective dosage, incomplete or inconsistent immobilization, or the requirement for two subsequent doses) for Rothschild's giraffe, black rhinoceros, hippopotamus, and cape buffalo (Buechner, *et al.*, 1960a; Lock and Harthoorn, 1959). Our findings on the field application of succinylcholine chloride to 121 individuals of 7 additional species of East African ungulates are presented below.

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METHODS

Delivery.—The immobilizing drug is injected into an animal by means of an automatic projectile syringe fired from a CO_2-powered pistol or rifle (Crockford, *et al.*, 1958; Talbot, 1960b). The syringe, rifle, and pistol are manufactured by the Palmer Chemical and Equipment Company of Atlanta, Georgia. Initially a great many problems were encountered in the use of this equipment under the field conditions involved. Except under ideal and rare conditions it is extremely difficult to approach East African wild animals for standing shots at ranges of 40 yd., the effective range of the rifle and pistol. In addition, the earlier equipment, while quite satisfactory at short ranges, was so erratic at the required longer ranges that quite a disproportionate amount of research time was spent in developing techniques of delivery. Much of the difficulty has been overcome by recent improvements in the equipment and approach techniques (Buechner, *et al.*, 1960a; Talbot, 1960b, 1960c). The Tanganyika Game Department currently uses a carefully prepared CO_2 rifle, fired from a stationary vehicle. The Wildlife Research Project initially used gun powder and CO_2-powered rifles, but now uses the CO_2 pistol fired from a moving vehicle; either the vehicle is driven relatively slowly past the target animal or chases it at relatively high speed for a short distance. Both techniques result in over 90 percent accuracy on larger animals. Delivery failure is now a rare problem, but the techniques must be carefully adapted to each change in field conditions.

Handling of immobilized animals.—When translocation of the animal is not involved, immediately following capture the animal is propped on its brisket, blindfolded, then variously marked, measured, sampled, and released (Lamprey and Whitehead, 1960; Talbot, 1960b). When succinylcholine chloride is used, it is essential to prop the larger animals such as wildebeests and zebras on their briskets as soon as possible, to reduce the danger of death through bloat, suffocation, and inhalation of stomach contents. The Uganda kob may be safely left lying on its side, and evidence from four individuals indicates that Thomson's gazelles and impalas may also be left on their sides while immobilized with succinylcholine chloride. When a curare-type immobilizing drug, Flaxedil (gallamine triethiodide) is used, even the smallest ungulates will die if left on their sides for several minutes (Talbot, 1960b).

Animals to be translocated are treated initially as above, then injected with a tranquilizer, Diquel or Largactil (chlorpromazine hydrochloride), before the effects of the immobilizer wear off. The initial tranquilizer dosage rate for adult wildebeests, Thomson's gazelles, and Grant's gazelles ranges from 0.5 to 1.0 mg./lb. Young animals require less, 0.5 to 0.7 mg./lb. Additional subsequent injections may be given as needed. The animals may then be kept under the tranquilizer for considerable periods (over 18 hr.) and transported by truck or Land-Rover.

Weight determination.—Dosage rates of succinylcholine chloride are expressed in milligrams of drug per pound of body weight. There is considerable variation between weights of individual animals of the same species in East Africa; consequently, for the dosage rates to be more than rough approximations, exact weights of the animals involved must be known. Where possible each animal captured has been weighed by means of an 1,120-lb. trade scale and a winch and derrick mounted on the rear of the Land-Rover. In addition, a series of weights and standard measurements for a total of 180 additional animals of the several species has been accumulated by the Project. In the cases in which the weight

of a captured animal could not be obtained directly, standard measurements were taken and by reference to the standard measurement tables and formulae derived from them, the animal's weight has been determined indirectly (Talbot and McCulloch, 1961). Except where otherwise noted, the dosage rates given below are based on these weight data.

Determination of dosage rates.—In zoological gardens the effective dosage rates have been determined by repeated injections of a single animal, starting at a very low dosage and gradually increasing it until an effective level was reached (Pistey and Wright, 1959). With free-ranging animals, repeated injection of an individual is seldom possible. The initial dosage has been based on the dosage for the most closely related animal as noted in the scanty literature, and subsequently altered up or down in accordance with the results. This has been a time-consuming process, especially in the earlier months when frequent syringe failure made it extremely difficult to deliver a known amount of drug. Recently improvements have been made in the syringe injection mechanisms, which make use of both the original soda–acid reaction and a new explosive cartridge injector (Talbot, 1960b). The improved syringes inject on impact with the animal, thus avoiding loss of contents through blowout in flight and making it possible to inject a precisely measured amount of drug.

The drug.—Succinylcholine chloride, or suxamethonium chloride, is one of a series of closely allied suxamethonium and decamethonium derivatives. These drugs are neuromuscular blocking agents, i.e., they produce immobilization by blocking nerve impulses from reaching their intended muscle. This block is accomplished by depolarization of the motor endplates, and the blocking action can be broken down only through hydrolysis of the drug by cholinesterases of the body. If an overdose of drug is given, the respiratory system is immobilized, and the animal dies before enough additional cholinesterase can be produced to reverse the action. There is no other true antidote known. Neostigmine sulphate is an antidote to curare and curare-type drugs, but not to succinylcholine chloride. The immobilizing action of succinylcholine chloride is not antagonized, but on the contrary, is potentiated by neostigmine (Pistey and Wright, 1960). When wildebeests, which had been immobilized with succinylcholine chloride, were injected with neostigmine (at 0.02 mg./lb.), they remained immobilized about 30 percent longer than the average of other wildebeests receiving the same dosage of succinylcholine chloride alone.

In human anesthesia, the "antidote" generally used with succinylcholine chloride is pure oxygen, provided with hospital equipment including an oxygen mask, a procedure unsuited for field use on large animals. Artificial respiration has been used to save several overdosed animals, but it has worked only in the case of very slight overdoses where voluntary respiration resumed in 2 to 5 min.

The effect of this drug on any species of animal apparently depends primarily on the animal's cholinesterase level, and the speed with which additional amounts of cholinesterase may be produced. These factors apparently vary greatly even between closely related species, and consequently, so do the effects of the drug. The reaction to the drug of any individual may also vary from time to time, depending on various factors including stress and daily variations in the plasma-cholinesterase level (Pistey and Wright, 1960).

Two forms of succinylcholine chloride were used in the present studies: a commercial solution in sealed ampoules, and a powder form from which sterile solutions were prepared as needed. Both the sealed injection preparation (under the trade names Midarine and Anectine) and the powder are produced by Burroughs Wellcome and Company, London and New York, and the following discussion and results refer mainly to these preparations. The results from six animals injected with another sealed preparation of succinylcho-

TABLE 1.—DOSAGE RATES OF SUCCINYLCHOLINE CHLORIDE[1] USED FOR IMMOBILIZATION OF FREE-RANGING EAST AFRICAN UNGULATES

Species and Number Drugged	Dosage (mg./lb.)			Minutes to Collapse	Minutes Immobilized
	Ineffective	Effective	Lethal		
Burchell's zebra (20)	0.290	0.360	0.420	2–11	8–22
Grant's gazelle (9)	0.100	0.130	0.150	4–9	15–27
Giraffe (6)	0.023	–	0.025	12	–
Impala (2)	–	0.185	–	1	29–160[2]
Thomson's gazelle (14)	0.210	0.250	0.280	4–7	17–26
Topi (6)	0.067	–	0.087	22	–
Wildebeest (58)	0.023	0.028–0.029	0.036	7–16	27–46
Uganda kob (46)[3]	–	0.159	0.200	3–7	20–60

[1] Dosage rates standardized to full strength, new Midarine or Anectine or succinylcholine chloride solution freshly prepared from powder.
[2] One hundred sixty-min. duration apparently due to location of injection.
[3] Buechner, *et al.*, 1960b.

line chloride, Scoline (Allen and Hanbury's Ltd., London), are presented separately below.

Under East African field conditions, succinylcholine chloride in solution is not stable. After comparison of results obtained by immobilizing a series of individual animals of the same species under comparable conditions with differently aged batches of Midarine and freshly mixed solution, the Tanganyika Game Department has determined the following rates of deterioration: Midarine from dealer's stock — approximately 12 percent per year; Midarine or fresh solution, kept under local field conditions and temperatures — approximately 10 percent per month. These rates appear to apply equally to Anectine, but refer only to the East African conditions encountered during the present studies. After taking the aging rate of the drug into account, the dosage rates given below and in the accompanying table have been standardized for full-strength fresh Midarine, Anectine, or solution freshly prepared from powder.

RESULTS

The results presented here and in Tables 1 and 2 refer to the forms of succinylcholine chloride described above: Midarine, Anectine, and powder solution. Preliminary experiments with four wildebeests and two topis indicate that different results may be obtained from other preparations of succinylcholine chloride. For example, the effective dosage of Scoline for wildebeests is 0.1 mg./lb., roughly 3.6 times the effective dosage of Anectine, Midarine, and the powder solution; and the effective dosage of Scoline for topi appears to be 0.18 mg./lb., roughly twice the minimum lethal dosage for the other preparations.

1. Uganda kob (*Adenota kob thomasi* (P. L. Sclater)[2]): The personnel of the Wildlife Research Project had the privilege of working briefly with H. K. Buechner on his successful kob capture project in Uganda (Buechner, *et al.*, 1960b). The

TABLE 2.—AVERAGE WEIGHTS AND ALLOWABLE ERROR IN WEIGHT ESTIMATION OF ANIMALS IMMOBILIZED

Species	Average Weight of Animals Drugged		Allowable Error in Weight Estimation[1]
	Male	Female	Percent of Actual Weight
Burchell's zebra	600	600	23
Grant's gazelle	161	103	16
Giraffe	2,000 est.	1,700	4
Impala	120	–	–
Thomson's gazelle	53	40	20
Topi	305	–	–
Wildebeest	461	360	7

[1] Allowable error in estimating target animal's weight for determination of dosage for satisfactory immobilization.
[2] Nomenclature follows Allen (1939).

kob has a wide tolerance to succinylcholine chloride and under proper dosage it will collapse in from 3 to 7 min., remaining completely immobilized for an average of about 40 min., then recovering quickly and completely. While immobilized, the kob can lie on its side safely, belching, with no apparent danger of death through bloat, suffocation, or inhalation of rumen contents. No other wild herbivore has proven to be such an ideal subject for field immobilization in general, or for succinylcholine chloride in particular (Buechner, *et al.*, 1960a; Crockford, *et al.*, 1957a; Hall, *et al.*, 1953; Pistey and Wright, 1959; Post, 1959; Talbot, 1960b).

2. Wildebeest (*Connochaetes taurinus albojubatus* Thomas): It has been more difficult to determine the effective dosage for wildebeests than for any other animal yet tested. A dosage of 0.002 mg./lb. below the effective dosage range (0.028–0.029 mg./lb.) requires over 27 min. to take effect and does not produce complete immobilization, while only 0.001 mg./lb. above the effective dosage is almost lethal and requires over 3 hr. for weakness and ataxia to wear off. Even within the very narrow effective dosage range succinylcholine chloride does not produce consistent results. The time required for initial collapse varies from 7 to 16 min., and incomplete immobilization is obtained in about 25 percent of the cases. Wildebeests must be kept on their briskets while immobilized, as 3 to 4 min. of lying flat results in death. Succinylcholine chloride is an effective drug for immobilization of wildebeests, but its field application is difficult and field results are not consistent.

3. Topi (*Damaliscus korigum topi* Blaine): On the basis of experiments to date with six animals, topis appear to be unsatisfactory subjects for field immobilization with succinylcholine chloride. If these findings are indicative, the animal's tolerance range for this drug must be very narrow and a safe dose should take well over 20 min. to take effect, a fact which would render use of the drug impractical under most field conditions.

4. Giraffe (*Giraffa camelopardalis tippelskirchi* Matschie): Six dartings have been carried out on giraffes with succinylcholine chloride, two by us and four by co-workers (Talbot, 1960c). A dosage of roughly 0.02 mg./lb. and less was ineffective on three females and one male. One female which received roughly 0.023 mg./lb. became slightly ataxic at 18 min. but did not collapse. Another female which received 0.025 mg./lb. collapsed at 12 min. and died 6 min. later. Apparently the best effective dosage is in the region of 0.024 mg./lb. These findings indicate that the giraffe's tolerance range to succinylcholine chloride is critically narrow, so that effective application of the drug to animals in the field would require estimation of the target animal's weight to within about 4 percent.

It is interesting to note that the succinylcholine chloride dosage for female Rothschild's giraffe (*Giraffa camelopardalis rothschildi*) published by Buechner, *et al.* (1960a) is 0.08 mg./lb., three times the above findings for the Masai giraffe. The difference may be due to intraspecific variations in the cholinesterase level, age of the drug, or to the methods of delivery employed. In the case of the Rothschild's giraffe the dosage was delivered in two chemical-reaction-injecting darts fired 15 min. apart (Buechner, *et al.*, 1960a); our dosages were injected by a single cartridge-injecting syringe (Talbot, 1960c).

5. Thomson's gazelle (*Gazella t. thomsonii* Günther): Very little difficulty has been experienced in immobilizing Thomson's gazelles. Owing to the small size of the animals, slight inaccuracies in shooting have resulted in injections into the thoracic cavity on three occasions and these have proved fatal. Two males have remained lying on their sides while immobilized without apparent ill effects. All others have been supported upright on their briskets with their heads held up.

6. Grant's gazelle (*Gazella g. granti* Brooke and *Gazella granti robertsi* Thomas): After the optimum dose for this species had been established no deaths oc-

curred. On every occasion the animals have been supported on their briskets and have had their heads held up to reduce the risk of bloat and the inhalation of rumen contents. One adult male which had received a heavy dose (0.145 mg./lb.) was given artificial respiration when its breathing stopped. After a period of 2 min., breathing was resumed and the animal recovered.

7. Burchell's zebra (*Equus burchelli böhmi* Matchie): The majority of the zebras immobilized with succinylcholine chloride have been excellent subjects and the species has a relatively wide tolerance range with this drug. However, the tolerance appears to vary among individuals and several deaths have occurred when an apparently safe dose had been injected. Of interest is the fact that Lock and Harthoorn (1959) reported on the basis of one animal the effective dose for captive Grevy's zebra (*Equus grevyi*) is 0.090 mg./lb., which is one-fourth of the effective dose for wild Burchell's zebra. The difference in tolerance to the drug between two such closely related species is very surprising and might be due to a difference in the cholinesterase level, age of drug, delivery technique, or variation between captive and wild individuals.

Immobilized zebras were held on their briskets with their heads supported. This procedure was found to be necessary because of the animals' tendency to raise the head momentarily, a movement which is followed immediately by the collapse of the head and a resultant damaging blow when the chin hits the ground. The immobilized zebras were handled by means of a head stall designed for this purpose (Lamprey and Whitehead, 1960). This equipment consists of a halter, with blinders, holding ropes, and a quick-release catch, so that the animal may be held in the proper position until it recovers, then released quickly and safely.

8. Impala (*Aepyceros melampus suara* (Matschie)): Two impalas have been immobilized to date with doses ascertained for kob. Both animals, young males, collapsed in a period of less than 1 min. This unusually short period has very great advantages because it enables the operator to find the animal quickly even when it runs into thick scrub. Both animals remained lying on their sides until they recovered.

DISCUSSION

Advantages.—On species with a relatively high tolerance to succinylcholine chloride, the drug is an effective and satisfactory field immobilizer. In such cases immobilization takes effect rapidly, and it is not preceded by an excitatory stage; immobilization is complete for a period averaging around 30 min., after which there is rapid recovery. No antidote is required and no additives, such as atropine, have been found necessary with the animals immobilized to date. Succinylcholine chloride is not caustic, having no apparent effect when spilled on human skin or even splashed in the eyes. An animal killed with the drug can be safely eaten. In the majority of animals immobilized with succinylcholine chloride there have been no signs of distress. More surprising is the apparent absence of fear which several zebras and wildebeests have shown while immobilized. Some have lain with their heads held up and an alert look in the eyes and with ears pricked forward, taking an obvious interest in their surroundings with no signs of alarm.

Limitations.—There is a wide variation in the resistance to succinylcholine chloride between species and occasionally, between individuals of the same species. Characteristically, with any animal there is a relatively narrow range of tolerance to the drug, so that to determine a dosage that will be neither ineffective nor lethal, the target animal's weight must be estimated quite closely. In the case of wildebeests and giraffes, the degree of weight estimation accuracy required is around 5 percent, and on such species, general field application of the drug is certain to result in a large percentage of escapes or fatalities. On one species, topi, it appears that not only is the dosage range extremely critical, but an effective dose requires too long to take effect.

The Wildlife Research Project has found Flaxedil (gallamine triethiodide) to be a more satisfactory drug than succinylcholine chloride for field immobilization of topis and wildebeests (Talbot, 1960b) and experiments are in progress to determine the suitability of Flaxedil for immobilization of giraffes.

A further limitation to succinylcholine chloride's desirability as a field immobilizer is its instability when kept under field conditions. However, this difficulty can be overcome by an accurate assessment of the rate of deterioration under a given set of conditions.

The drug's action is irreversible, and there is no known field antidote; consequently, extreme care must be exercised to protect both the operator and the animal.

The effect of any immobilizing drug on an animal depends on such factors as placement and method of injection; the animal's age, sex, weight, and condition; the animal's movements prior to and following injection; and individual characteristics (Talbot, 1960b). Just as the reaction of humans to a given drug may vary greatly, some individuals having greater and some lesser resistance to it, there are considerable variations in drug resistance among individuals in any wild species. In addition, external factors such as temperature and humidity may affect the condition of the drugs and equipment. Consequently, it does not appear valid to generalize on the effects of any drug on the basis of experiments with a few specimens, and the results obtained under one set of conditions may not apply consistently to a different situation.

SUMMARY

This paper presents the results to date of the use of the neuromuscular blocking drug, succinylcholine chloride, on 121 individual animals of 7 species of wild ungulates. The use of the drug in field immobilization is briefly reviewed. Methods are described, including delivery of the drug, handling and translocation of immobilized animals, weight determination, and dosage rate determination. The mode of action of succinylcholine chloride, rates of deterioration, and factors influencing its effect on individual animals are discussed, as well as the advantages and limitations of its use in the field.

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THE WILDLIFE SOCIETY

REPORT OF THE EXECUTIVE SECRETARY FOR THE YEAR 1960–61

Membership

The steady growth of the Society continues. For the first time membership climbed over the 3,000 mark and total non-member subscriptions to THE JOURNAL numbered more than 600. The 1960–61 Society year saw 328 new regular members added to the roster. Under the leadership of Chairman Wendell Swank, a full-scale member recruitment program, in which all members are urged to participate, is now being launched by the Membership Committee.

Of more than passing interest is the increase of more than 100 percent in Life Memberships. A few of these are new members, but most were changeovers from annual membership. This increase was stimulated by the impending rise in annual dues. The trend toward Life Memberships ceased abruptly when the membership agreed to raise the Life Member fee to $200 as of January 1, 1961. This was necessary in order to protect the financial welfare of the Society since the income from the Life Member fees must be depended upon to pay the costs of these memberships.

A summary of membership status over the period 1953–60 is given in Table 1.

The Society suffered the loss of the following members through death: George Frederick Boyer, William J. K. Harkness, Leonard M. Llewellyn, and Richard W. Westwood.

Publications and Editorial Affairs

Under the able guidance of Editor Charles M. Kirkpatrick, THE JOURNAL OF WILDLIFE MANAGEMENT continues its eminent position in the wildlife management field. Assisted by Associate Editor Frank F. Hooper and a 15-man Editorial Board, more than 100 manuscripts were received and considered for publication. However, the number submitted was 40 less than in 1959. The current backlog of suitable papers is low. Members are urged to submit papers for consideration with emphasis on longer papers which will print at seven pages or more.

WILDLIFE MONOGRAPHS No. 4 and No. 5 were published during 1960 and distributed to members and subscribers. These numbers were sponsored by the New York Zoological Society and The Conservation Foundation, and represent fine contributions to this valuable series of longer wildlife papers. Editor Louis A. Krumholz continues his fine work and reports that four more manuscripts have been accepted, including the first fish paper to be included in the series. The Sport Fishing Institute is the sponsor of the fish paper. It is anticipated that the four papers will be published as WILDLIFE MONOGRAPHS in 1961.

THE WILDLIFE SOCIETY NEWS has grown to six pages under the effective care of Editor Thomas R. Evans. The objective is to include an increasing amount of information useful to the members. The Employment Service function is available to all members and employers, and members are encouraged to contribute items of general interest.

The Manual of Game Investigational Techniques came off the press in 1960 and became an instant

TABLE 1.—WILDLIFE SOCIETY MEMBERSHIP 1953–60

Class of Membership	ENROLLMENTS AT THE END OF THE CALENDAR YEAR							
	1953	1954	1955	1956	1957	1958	1959	1960
Honorary	13	15	17	18	18	18	20	21
Life	10	17	27	31	66	80	113	238
Regular	2,140	2,346	2,503	2,485	2,619	2,720	2,862	2,924
Subscribers	377	406	429	441	501	507	538	602
Total	2,540	2,784	2,976	2,975	3,204	3,325	3,533	3,785

TABLE 2.—STATEMENT OF RECEIPTS AND DISBURSEMENTS 1960–61

RECEIPTS			
Bank balance February 27, 1960			$53,984.89
Receipts (deposited to checking account)			
Dues, annual	$16,740.00		
Life Member payments (pending trans. to savings)	75.00		
Subscriptions	3,793.00		
Sustaining membership	100.00	$20,708.00	
Sales:			
JOURNAL (back issues, single issues)	743.60		
MONOGRAPHS, Indices, etc.	539.10		
Techniques Manual	6,804.50		
Reimbursement on MONOGRAPH No. 4	4,519.79		
Misc. receipts	40.57	$12,647.56	
Receipts (deposited to savings accounts)			
Dividends and interest	1,708.77		
Life Membership payments	6,425.00	$ 8,133.77	$41,489.33
			$95,474.22
DISBURSEMENTS			
Publications			
JOURNAL, printing	$10,587.35		
NEWS, printing	1,390.29		
MONOGRAPH No. 4, printing	4,469.39		
MONOGRAPH No. 4, editorial costs	530.00		
MONOGRAPH No. 5, printing	1,666.27		
MONOGRAPH No. 5, editorial costs	165.00		
MONOGRAPHS editor, postage and misc. costs	103.63		
Techniques Manual, printing	5,279.44		
Techniques Manual, mailing bags	127.80		
Maintenance of stencils, postage, and mailing	1,042.73		
Technical Writers Handbook, artwork & contrib.	963.51	$26,325.41	
JOURNAL Editor's expenses			
Editorial assistance	1,134.00		
Postage and misc. costs	360.97	$ 1,494.97	
Honoraria (three editors)	600.00	$ 600.00	
Executive Secretary			
Honorarium	700.00		
Clerical assistance	1,372.75		
Moving, travel, and misc. costs	140.50	$ 2,213.25	
General Supplies (postage, communicaitons, ballots, dues notices, stationery, etc.)	1,862.83		
Annual Meeting expenses (awards, employment desk)	83.48		
Miscellaneous			
Affiliation dues (I.U.C.N., Int. Comm. Bird Pres., Watershed Congress)	200.00		
Refunds, bank charges, bad checks, binding, invent.	202.03		
Audit	35.00	$ 2,383.34	
		$33,016.97	$33,016.97
Bank balance, February 28, 1961			$62,457.25

success. Much credit for this is due to its editor, Chairman of the Manual of Wildlife Techniques Committee, Henry S. Mosby, and his colleagues. The 2,000 copies printed were sold and many unfilled orders are on hand. The Council approved the reprinting of 1,000 additional copies, which will be available in March 1961. This useful manual will continue as a responsibility of the Committee and will be revised and reprinted as necessary to keep its contents up-to-date. It has already paid for itself and for its first reprinting.

Grateful acknowledgment is given to Purdue University, The University of Louisville, the Illinois Conservation Department, and The Virginia Polytechnic Institute for their generous support of the editorial functions outlined above (in the order listed). Perhaps few members realize the extent of this support, which is indeed substantial.

In cooperation with the American Conservation Association, the National Wildlife Federation, and the American Fisheries Society, Werner Nagel's *Make Your Technical Writing Useful* was published. This fine handbook for writers, useful in both technical and popular wildlife writing, is now available for $1.00 through the courtesy of the American Fisheries Society, Box 492, McLean, Virginia. (Bulk rates are available on request.)

Action on Proposed Bylaws Revisions

The Constitution and Bylaws Committee, under the chairmanship of Gustav A. Swanson, proposed several Bylaws revisions which were aimed at

TABLE 3.—STATEMENT OF ASSETS AND LIABILITIES, FEBRUARY 28, 1961

ASSETS		
Cash		
Checking Account (Bank of Bethesda)	$17,363.98	$17,363.98
Savings Accounts (Operating)		
Bank of Silver Spring, Acct. No. 10282	3,743.01	
Bank of Silver Spring, Acct. No. 15147	1,100.14	
Guardian Federal Savings, Acct. No. 19671	5,295.26	10,138.41
Savings Accounts (Permanent Fund)		
Emigrant Industrial Savings Bank, Acct. No. 1463873	9,602.39	
Perpetual Building Association, Acct. No. S131-490	9,589.51	
Loyola Fed. Savings & Loan Assoc., Acct. No. 95954	9,299.48	
Home Building Assoc. of D. C., Acct. No. 8150	6,463.48	34,954.86
		$62,457.25
Securities		
45 Shares State Street Investment Corp. at $39.83 (Bid price on 2/24/61)	$ 1,792.35	
96 Shares Loomis–Sayles Mutual Fund, Inc. at $15.64 (Bid price on 2/24/61)	1,501.44	
U. S. Treasury Note, Series A (No. 17393)	1,000.00	$ 4,293.79
Total Assets		$66,751.04
LIABILITIES		
Liabilities		None
*Net Worth		$66,751.04
Total Liabilities and Net Worth		$66,751.04

*Excludes back issues and other publications on hand of indefinite value.

strengthening the Society and expanding its program. These included the following proposals:

1. to increase annual dues to $15 and Life Member payments to $200;
2. to create a Student Member class with dues at $6;
3. to create classes of Official Member ($50) and Sustaining Member ($100);
4. to provide a system of electing Regional Representatives for three-year staggered terms of office;
5. to provide for the nomination of Regional Representatives by the Nominations Committee; and
6. to give authority to the Council to modify Regional Boundaries.

When presented to the membership by ballot, all proposals except the dues increase were approved by substantial majorities. The annual dues and Life Member payment increase proposals were defeated. Details of the voting were published in the August 1960 WILDLIFE SOCIETY NEWS.

At a special meeting of The Wildlife Society Council called by President Cheatum and held in Denver, Colorado on September 14, 1960, the Council reviewed the results of the balloting and agreed to submit a revised dues increase proposal to the membership. This proposal was described in the November 1960 NEWS and was submitted to the membership by ballot in December. It provided for a referendum on whether or not an annual dues increase was desired. In addition, the options of $10 and $15 annual dues payments were offered. An increase of Life Member payments to $200 also was proposed.

A record vote of the membership favored a dues increase by 1,548 to 432. The $10 annual dues option prevailed by a substantial margin, and the increase in Life Member payments also was adopted. Details of the voting were published in the February 1961 NEWS.

All of the amendments to the Bylaws which were approved by vote of the membership will become effective in 1962 except the increase in Life Member payments which became effective as of January 1, 1961.

Organization of Society Business Functions

Consideration was given by the Council to proposals for revising the business functions of the Society in order to promote more efficient operations and to place the Society on a more nearly self-sustaining basis. These included the possibilities of employing a full-time Executive Secretary, the coordination of business operations with those of the American Fisheries Society, and the utilization of business management services available from the American Institute of Biological Sciences. Decisions would be influenced by action of the membership on the proposed Bylaws amendments which will be considered by the Council.

Election of Officers 1961–62

The Nominating Committee, under Chairman Fred S. Barkalow, nominated E. L. Cheatum and W. Winston Mair for President, and Jack Berryman and W. C. Glazener for Vice-president. Cheatum and Berryman were re-elected.

Nominees for Regional Representatives selected by vote of the membership were as follows, the first named being the winning candidate: Region 1, Malcolm W. Coulter and W. R. DeGarmo; Region 2, Leslie L. Glasgow and H. E. Wallace; Region 3, Bill T. Crawford and Ralph MacMullan; Region 4, Lee E. Yeager and Ralph R. Hill; Region

5, Wendell G. Swank and Samuel H. Lamb; Region 6, Jessop B. Low and Howard R. Leach; Region 7, C. David Fowle and David A. Munro.

All ballots on Bylaws amendments and elections were counted by the Audit and Elections Committee, Winston E. Banko, Chairman.

Affiliations and Representation at Meetings

The Society continued its affiliations and cooperation with the International Council for Bird Preservation, the International Union for the Conservation of Nature and Natural Resources, the International Wildlife Biologists' Congress, the National Research Council, the National Watershed Congress, and the Waterfowl Advisory Committee.

Society Sections

All Sections were active during the year. Reports on their meetings and activities are published in the NEWS.

Financial Report

The Society continues in a sound financial condition, and its assets and net worth continue to grow. Income from funds in savings accounts, dividends, and increased values of securities provided a return of about 4.75 percent. Due largely to substantial contributions of time and effort, a surplus of about $2,000 in income over expenditures was realized in the operating account.

Adjustments were made in operating fund savings accounts to reduce an accumulation in one which exceeded the insurable limit, and one new savings account was established. The Permanent Fund of the Society increased substantially during the year as a result of increased numbers of Life Members. A new savings account was established to accommodate these funds.

The Society books were closed for the 1960–61 fiscal year on February 28 and audited on the same date. A detailed account of Receipts and Disbursements for the year and a statement of Assets and Liabilities are given in Table 2 and Table 3 respectively.

ACKNOWLEDGMENT

The Executive Secretaryship passed from Joseph P. Linduska to the undersigned on September 1, 1960. The Society members, and particularly the present Executive Secretary, are indebted to Dr. Linduska for his generous contributions of time, effort, and wisdom during his 3 years of service, and for the excellent condition of the records and books which he turned over to his successor.—Respectfully submitted, C. GORDON FREDINE, Executive Secretary.

MINUTES OF THE WILDLIFE SOCIETY COUNCIL MEETING, MARCH 5, 1961

The Council met on March 5, 1961, in The Statler–Hilton Hotel, Washington, D. C. The meeting was called to order by President E. L. Cheatum at 9:45 a.m. Other Council members present were Charles A. Dambach, Past President; Jack Berryman, Vice-president; and regional representatives as follows: Region 1, W. R. DeGarmo; Region 2, Leslie L. Glasgow; Region 3, Howard Wight (alternate for Bill T. Crawford); Region 4, Lee E. Yeager; Region 5, Wendell G. Swank; Region 6, Jessop B. Low (alternate for Howard R. Leach). Others present as advisors were Malcolm Coulter, J. J. Hickey, Charles M. Kirkpatrick, Henry S. Mosby, J. P. Linduska, Gustav A. Swanson, John Seubert, and the Executive Secretary. Kenneth D. Carlander represented The American Fisheries Society.

The President called upon the Executive Secretary for a report of Society affairs. A detailed written report being available to the group, his oral report was limited to a brief discussion of activities, financial affairs, and the status of membership. The report was accepted with minor amendments.

Next were the reports of Standing Committees. Most of these will be published in THE JOURNAL OF WILDLIFE MANAGEMENT or THE WILDLIFE SOCIETY NEWS. Following are résumés of special points made and actions taken.

Chairman Swank announced for the Membership Committee that a membership recruitment drive was under way. He suggested that an up-to-date membership list should be made available; this can be done on a state-by-state basis through the cooperation of the Society's printer on tapes or cards. Plans were discussed for announcing and securing members in the new Student, Official, and Sustaining Member classes.

Chairman J. J. Hickey reviewed the work of the Professional Training and Employment Committee and recommended that the employment service be continued for another year. The status of the professional studies was reviewed, and the first of two reports will be published in the April 1961 JOURNAL. John V. K. Wagar has agreed to arrange for the preparation of the second report. Concern was expressed that the printing of two separate viewpoints would create a division and tension within the Society, particularly among those engaged in university work. The plan is to coordinate the two reports eventually into a single statement after the membership has had an opportunity to see and comment on them.

John Seubert reported on behalf of Chairman Stewart Brandborg for the Code of Ethics Committee. A revised draft of the Code of Ethics was reviewed by the Council and several amendments were made. It was decided that the Code as revised by the Council should be returned to the Committee for editing, that the Council approve the subject matter it now contains, and that the Code be resubmitted to the Council for final ac-

tion authorizing its submission to the membership for consideration.

No report from the Committee on Relations with the Canadian Society of Wildlife and Fishery Biologists was available, and its work was continued for another year with a view toward its completion.

Charles Dambach and Kenneth Carlander, for the Committee on Cooperation with The American Fisheries Society, reported on progress made jointly with the corresponding committee of the American Fisheries Society. Recommendations were made to provide for general cooperation between the executive secretaries of the two societies as a matter of official policy. The Committee is to continue its work, seeking to meet at least once a year with the corresponding committee of the American Fisheries Society and report annually to the Council. No basis for joint business operations of the two societies is considered feasible at the present time.

The written report of the Committee on African Wildlife was accepted and will be published.

The written report of the Committee on Economic Losses Caused by Vertebrates was accepted. Comments on questions raised by the committee on the definition of "wildlife" with respect to Society usage were to be prepared by Dr. Dambach.

For the Committee on Constitution and Bylaws, Dr. Swanson submitted the following proposed amendments to the Bylaws and action was taken as indicated:

1. "That a Foreign Member class be established with dues at $8.00." Action: The Council was divided on this question. All members agreed that the Society wishes to encourage foreign memberships, but some doubted that a reduced membership fee was proper even if the right to vote were denied such members, and that further study of the question was warranted. A motion made and seconded to adopt the proposal to create a Foreign Member class failed to pass.

2. "That provision be made for the Council to appoint an alternate Executive Secretary, who could, upon the request of the President and/or the Executive Secretary, discharge the essential duties of the Executive Secretary in his absence or inability to serve." Action: The proposal was adopted.

3. "That provision be made for Chapters of the Society to encourage and facilitate the organization and affiliation of smaller, local, active groups." Action: The Bylaws Committee was instructed to draft suggested Bylaws for the Chapters and to prepare specific Bylaws language changes, as authorized at the Denver Council Meeting, to be submitted to a vote by members as soon as possible.

Both of the approved proposals are to be submitted to the membership for action at the same time.

For the Wildlife Techniques Manual Committee Dr. Mosby reported on the sellout of the first printing of 2,000 copies of the *Manual* and the reprinting of 1,000 additional copies. His report was accepted with commendations.

Next the editors of Society publications were called upon for reports.

Editor Kirkpatrick reviewed the year's work on THE JOURNAL OF WILDLIFE MANAGEMENT. He showed that although there has been a regrettable slacking off of manuscripts submitted, 38 major articles, averaging 8.4 pages in length, were printed in Volume 24. The printing costs per page go up as the Society grows. In 1958, 3,600 printed copies cost $20.87 per page. In January 1961, 4,200 copies cost $23.62 per page.

The Editor's report was accepted with thanks for his fine efforts. The Editor was instructed to prepare a statement to go to state game administrators advising that THE JOURNAL is available for publishing major articles on wildlife management, the reprints of which could be covered with the official state-designed cover. This statement is to be ready for submission at the time of the next International Association of Game and Fish Commissioners' Conference.

Since Editor Krumholz was unable to attend, his report for WILDLIFE MONOGRAPHS was read and accepted. Upon his recommendation, the Council went on record favoring the Society's sharing of distribution costs, which now are borne largely by the sponsor, and the making of a study to determine an equitable basis for such sharing. A report on this proposal is to be made to the Council at its next meeting. Four additional MONOGRAPHS have been accepted and are expected to be published this year.

The report of Editor Thomas Evans for THE WILDLIFE SOCIETY NEWS was read and accepted. He was commended on the improved format and content of THE NEWS.

Next the Council considered at length the opportunities for affiliation with the American Institute of Biological Sciences and the utilization of its Business Management and Redactory Services. It was determined that the Society would benefit from such an affiliation and that the costs thereof would be within the financial means of the Society when the adopted increase in annual dues becomes effective. The Council agreed to apply for an Affiliate membership for the Society in the AIBS and to use its Business Management and Redactory Services. These services would begin at such time as might be required to make them fully effective during 1962.

The Council agreed that the Society membership should be polled to seek its approval of a full Membership in AIBS for the benefit of Society members and to contribute to the advancement of the science of biology through AIBS.

The Council then considered the implementation of Bylaws changes which had been approved by the membership.

1. The Executive Secretary is to make suitable arrangements for certifying Student Members.

TABLE 1.—BUDGET FOR 1961–62

Publications	
JOURNAL, printing	$11,500.00
NEWS, printing	1,400.00
Maintenance of stencils, postage, mailing, etc.	1,800.00
MONOGRAPHS—Editorial, printing, and mailing (reimbursable)	10,000.00
Techniques Manual, reprinting and freight	2,000.00
Brochure on the Wildlife Profession	1,000.00
Editorial Expenses	
JOURNAL, supplies, postage, misc.	500.00
JOURNAL, editorial assistance	1,500.00
JOURNAL, travel of editor	200.00
MONOGRAPHS, supplies, postage, misc.	200.00
Honorarium for editors	900.00
Executive Secretary	
Clerical assistance	2,500.00
Travel and meeting expenses	200.00
Honorarium	800.00
AIBS Business Services	2,358.00
General supplies, dues notices, ballots, communications, postage, etc.	1,600.00
Annual meeting expenses	175.00
Affiliations	325.00
Miscellaneous charges, audit, bank charges, etc.	200.00
Contingency reserve	2,000.00
TOTAL	$42,158.00
Less reimbursement in full for MONOGRAPHS	10,000.00
Less reimbursement from *Techniques Manual* sales	3,500.00
NET OPERATING EXPENSES	$28,658.00
Anticipated receipts from dues, sales, and investments	$30,000.00

2. A study will be made of procedures to be adopted for handling Official and Sustaining Memberships.

3. A committee is to be named, including the Regional Representatives, to refer to the previous study on Regional Boundary adjustments and to prepare recommendations to the Council. Lee E. Yeager is to act as chairman with authority to select the other members.

4. An unavoidable delay of 1 year occurred in beginning the procedure of electing Regional Representatives for staggered terms of 3 years. The nominations of Regional Representatives by the Nominating Committee under the adopted plan will be initiated this summer and fall.

The Council considered the subscription rate for THE JOURNAL OF WILDLIFE MANAGEMENT. It was decided to increase the subscription rate to $10, to coincide with the increase in membership dues, beginning in 1962. The subscriptions will continue to include WILDLIFE MONOGRAPHS in the years they are published.

The Council agreed to continue to support and participate in the affairs of the organizations with which the Society is now affiliated. The President was empowered to make decisions respecting the statements of the Society presented at their meetings.

The Council considered the statement prepared by James Lee on wildlife management as a profession. The members agreed to submit suggested revisions to the President, who will coordinate them for submission to Mr. Lee with further instructions as to planning for its appearance as an official brochure of the Society on this subject.

The reported operations of a "North American School of Conservation" were considered by the Council. Lacking sufficient data on which to pass judgment, the Regional Representative, Region 6, was requested to obtain additional pertinent information regarding the standards of this school.

The Council revised and approved the budget for 1961–62, which includes funds for initiating the Business Management and Redactory Sedvices of the AIBS as may be required. (See Table 1.)

The term of Daniel L. Leedy as Trustee having expired, the Council thanked him for his fine service and appointed Joseph P. Linduska to succeed him as Trustee for 3 years.

The present Executive Secretary was reappointed with a commendation for his services. It was agreed that the President shall explore the possibility of obtaining a foundation grant to finance a full-time executive secretary, and that he shall appoint a committee to define the duties and functions of an executive secretary for Society affairs on a full-time basis.

The Council reappointed the present editors,

with great appreciation expressed for their fine contributions of knowledge and labor.

Regional Representative-elect for Region 6, Jessop B. Low, at the request of the California Section of The Wildlife Society, presented resolutions adopted at the Section business meeting on January 28, 1960.

Resolution No. 2: the Council appreciates and agrees with all the parts of this resolution except part 1. The Council believes that the Society from its founding has been a professional society, and cannot agree that the Society "should remain essentially a technical Society."

Resolution No. 3: the Council moved that the California Section be advised that this resolution, requesting that Society funds be used to defray the travel expenses of Regional Representatives to Council and Annual Meetings, has not been incorporated in the program developed over the past several years and its adoption is not possible at the present time.

Resolution No. 5: the Council takes due note of the tone of reprimand to the Council included in the discussion of this resolution which pertains to alleged unethical methods of presenting the ballot on a dues increase to the membership. The Council disagrees with the allegations and will welcome an opportunity to defend its action.

On invitation from President Cheatum, the Council offered nominations for Honorary Membership. Ernest F. Swift and George W. McCullough were proposed. By action of the Council their names were approved for presentation to the members for consideration at the Annual Meeting.

There being no further business, the meeting was adjourned by the President at 12:45 a.m., March 6.—Respectfully submitted, C. Gordon Fredine, Executive Secretary.

MINUTES OF THE ANNUAL BUSINESS MEETING, MARCH 6, 1961

The annual business meeting of The Wildlife Society was held in The Statler–Hilton Hotel, Washington, D. C. The annual dinner preceding the meeting was attended by 136 members and friends at The Manger Hamilton Hotel. Presentations of the Society's Terrestrial Wildlife and Fisheries Publication Awards and the Conservation Education Award were made by President Cheatum following the dinner.

The meeting was called to order at 8:20 p.m. by President E. L. Cheatum. A motion by Wendell Swank to accept the minutes of the last annual meeting, which had been published in THE JOURNAL OF WILDLIFE MANAGEMENT, Vol. 24, No. 3, was seconded and approved by the membership.

Upon being called upon for his report, the Executive Secretary referred the members to copies of his written report which were available in the meeting room, and briefly commented on highlights of the activities during the year. He called attention to the steady growth in membership and the financial soundness of the Society. He acknowledged the fine service rendered by the editors of the Society publications and by past Executive Secretary Joseph P. Linduska.

The President followed with his report and complimented the officers and Regional Representatives on their excellent work during the year. He then called upon the Executive Secretary for a reading of the minutes of The Wildlife Society Council Meeting held on the previous day. (See Minutes, Council Meeting, March 5, *supra.*) President Cheatum elaborated on certain actions of the Council. He explained that the Council did not approve a special "foreign member" class because it was the consensus that as far as the Society was concerned none of the members is a "foreigner," and all are considered to be equal partners regardless of their residence. He commented also on the need to increase the subscription rate for THE JOURNAL OF WILDLIFE MANAGEMENT to a level equal to that of annual membership dues. He expressed his views concerning the critical attitude of the California Section toward the Council's action respecting the resubmission of a dues increase proposal to the membership, and urged that every effort be made to clear up misunderstandings so that the Society could move forward in unity.

A question was raised from the floor regarding the type of membership in the American Institute of Biological Sciences which had been approved by the Council. It was explained that the Council had agreed to apply for an Affiliate Membership for the Society as an organization rather than a full Membership. This would obligate the Society to an annual affiliate membership fee of $300 for an organization such as ours with 3,000 or more members. Certain benefits would accrue to the Society and its members from this arrangement, particularly since the Society was planning to utilize the Business Management and Redactory services of the AIBS. Because a full membership in AIBS would obligate an annual membership fee of $1 for each member of the Society, the Council considered that a decision to adopt this type of membership properly should be referred to the whole Society for action. It is the intention of the Council to submit this question to the Society members at an appropriate time.

At this point Council action on March 5 recommending two individuals for Honorary membership was considered. Past President Charles A. Dambach submitted the nomination of George W. McCullough, and reviewed the nominee's long and faithful service in the field of wildlife conservation. C. P. Gutermuth warmly endorsed the nomination. The Executive Secretary, speaking for Lee Yeager and also in his own behalf, nominated Ernest F. Swift and reviewed his outstanding career. His nomination was seconded by Gustav Swanson and

Adolph Stebler. The members unanimously approved the nominations, and President Cheatum declared both nominees elected to Honorary membership in the Society.

President Cheatum referred to the Society awards presented earlier in the evening and invited comments from the chairmen of the committees making the selections. Joseph Shomon reviewed the interesting but difficult task of the Conservation Education Award Committee in making the selection from the number of fine publications submitted. He said that the Committee recommended that an honorable mention be given to co-authors Ansel Adams and Nancy Newhall for the excellence of their book, *This Is The American Earth*.

Other committee chairmen were invited to report on their work. Dr. Swanson explained the need for the Bylaws amendment proposals. Wendell Swank reported on the work of the Membership Committee, stating that in cooperation with the regional representatives the active participation of more than 60 members in membership recruitment had been organized. The cooperation of all members was requested. J. J. Hickey outlined the work of the Professional Training and Employment Committee, and Helmut Buechner commented on progress made on Society interests in African Wildlife. Charles Dambach reported on the fine and cordial relations that exist with the American Fisheries Society and the excellent opportunities for further cooperation. Henry Mosby reviewed the status and work of the Wildlife Techniques Committee. Inasmuch as most of these and other committee reports will be published, they are not reported in detail in these minutes. For this reason also the reading of reports of the regional representatives was dispensed with without objection from the members present.

No new business was presented or brought up by the members for consideration. However, Walter P. Taylor commented generally on the work accomplished during the year and complimented the officers and regional representatives on their efforts. He voiced appreciation for the leadership exhibited by the Council.

The members gave unanimous approval to a resolution presented by Malcolm W. Coulter expressing great appreciation to the Wildlife Management Institute for the many courtesies extended to the Society during the 26th North American Wildlife and Natural Resources Conference. The resolution also thanked The Statler-Hilton and The Manger Hamilton Hotels for the fine facilities and services rendered in connection with the Society meetings and annual dinner.

There being no further business, a motion for adjournment was seconded and passed unanimously. President Cheatum declared the meeting adjourned at 9:40 p.m.—Respectfully submitted, C. GORDON FREDINE, Executive Secretary.

ANNUAL REPORTS OF WILDLIFE SOCIETY COMMITTEES

The Aldo Leopold Award

The presentation of this award was made for The Wildlife Society by President E. L. Cheatum at the annual banquet of the 26th North American Wildlife and Natural Resources Conference, as follows:

"Each year The Wildlife Society has the privilege of honoring one of its most eminent workers, for a lifetime of distinguished service and outstanding accomplishments in the cause of conservation. This is done through awarding the Leopold Memorial Medal, the highest honor the Society has in its power to bestow.

"There are already eleven distinguished recipients of this coveted award: J. N. Darling (1950), Carl D. Shoemaker (1951), Olaus J. Murie (1952), Ira N. Gabrielson (1953), Harold Titus (1954), Clarence Cottam (1955), Hoyes Lloyd (1956), C. R. Gutermuth (1957), E. R. Kalmbach (1958), Ernest F. Swift (1959), and Enrique Beltran (1960).

"Tonight's favored recipient is another man whom we are proud to honor. Through a rich lifetime of service this friend of conservation has fostered and stimulated research, education and sound management of all renewable resources. He has traveled far and seen much. America is a better land because of him.

"For the federal and state governments and for several universities he has conducted and directed research in various parts of this continent and he has studied conservation and ecology in foreign lands including the Fiji Islands, New Zealand, Australia and countries in Europe and Asia.

"He is a great teacher who has fired many students with his own enthusiasm and zeal. He served seven years as a Curator of Mammals at the University of California. Subsequently he served as professor and lecturer in zoology and wildlife conservation and education at seven universities in six western and mid-western states. For more than a year he has served with the American Institute of Biological Sciences lecturing before high school and college students.

"He served as a leading professional in the old Biological Survey and in its successor agency, the U. S. Fish and Wildlife Service, for 35 years. He has been retired from government for more than ten years.

"He is a prominent writer and has co-authored the book, *The Birds of the State of Washington*, and edited the recent book, *Deer of North America*. In addition he has had published over 300 bulletins, monographs and papers on zoology, ecology and the conservation of natural renewable resources. He is no stranger to this conference; I might mention that since the North American

WALTER P. TAYLOR
Recipient of The Aldo Leopold Award in 1961

Wildlife Conferences have been held, beginning in 1936, he has given 11 papers in both its technical and general sessions. His influence and stimulation to younger men has been outstanding.

"His life has been guided by the highest of standards. He has long commanded respect, admiration and affection from his family, his associates and from the public. It is not surprising, therefore, that he holds the Distinguished Gold Medal Award from the U. S. Department of the Interior and was elected a Fellow of the American Association for the Advancement of Science, the Texas and the California Academies of Science, and Honorary Member of the American Society of Mammalogists.

"To me personally, he has been a hero for over 20 years and it is a special privilege for me, in behalf of The Wildlife Society, to present the Leopold Medal Award for 1961 to Dr. Walter Penn Taylor, a veteran in conservation, and, 72 years young!"

African Wildlife

A three-stage "African Special Project," limited to tropical countries, has been launched by IUCN. Stage I, which began in late 1960, involves discussions of principles and practices of conservation with leaders of African opinion under the leadership of Mr. G. G. Watterson, formerly of the FAO African Regional Office and now Secretary-General of IUCN. A small group of African persons will accompany Mr. Watterson during his tour in Africa. The purpose of these discussions is to prepare for Stage II, "A Conference on the Conservation of Nature and Natural Resources in Modern African States," to be held in Arusha, Tanganyika, in September 1961. This conference will be in two parts: Part I—Technical Discussions. Approximately 3 days will be devoted to nature and natural resources in the wild lands of tropical Africa. Specialist workers mainly from Africa will attend this session. Part II—Administrative and Political Implications. For this session the scope is to be broadened to the application of conservation principles to land which has been brought into production and land where nature is still dominant. In addition to the members attending Part I, the conference would include leading African personages nominated by the African Governments or specially invited to attend. Stage III, which is to extend over a 2-year period (1961–62), will put into operation recommendations emerging from the conference. An experienced ecologist and an educational specialist are to be attached to IUCN. An African Advisory Committee (Dr. E. B. Worthington, The Nature Conservancy, Chairman; George Treichel, Staff Ecologist, IUCN, Secretary) has been formed to direct the program.—VICTOR H. CAHALANE, WILLIAM M. LONGHURST, GEORGE A. PETRIDES, NOEL M. SIMON, HELMUT K. BUECHNER, Chairman.

Code of Ethics

The first draft of the Code of Ethics was substantially revised after the Council of The Wildlife Society and the Code of Ethics Committee met in Dallas in March 1960. Copies of the second draft were provided to the Council members and further recommendations were solicited by the Committee for strengthening the Code. A number of helpful suggestions were made and these were subsequently incorporated in a third draft.

This third draft of the Code was then considered by the Council at the recent meeting in Washington. After resolving differences of opinion on portions of the Code, the Council endorsed the subject matter of the Code, but suggested further condensation. Once this has been done, and after final approval of the Council, the shortened Code will be presented in the NEWSLETTER to the membership of the Society for their consideration.—Respectfully submitted, JAMES SALINAS, JOHN L. SEUBERT, AND STEWART BRANDBORG, Chairman.

Conservation Education Award

The Conservation Education Award Committee, as usual, had a busy year. A total of 11 nominations, embracing 3 main groups or categories of endeavor—publications, general programming, and films—were considered. Though a number of outstanding pieces of work were submitted as exhibits and reviewed, the Committee in its deliberations was guided by the criteria established by the original committee. These criteria were that pro-

grams and projects covering the broad field of renewable resources conservation embodying basic principles and concepts should be given first consideration; also that works which have some national significance should be recognized.

With these guidelines in mind, the Committee voted to give the 1960 Conservation Education Award to Byron L. Ashbaugh and Muriel Beuschlein for their text and teaching guide entitled *Things to Do in Science and Conservation* sponsored in 1960 by the Conservation Education Association in cooperation with the American Nature Association.

The Committee further recommended that an honorable mention be given to co-authors Ansel Adams and Nancy Newhall for their work of great beauty and excellent quality, *This is the American Earth*, published by the Sierra Club in 1960. Normally two awards in the same category are not made, but since in the committee's judgment the two books were of altogether different character, it was felt that in this instance the honorable mention should be made.—Respectfully submitted, ROBERT K. DAVIS, DOUGLAS E. WADE, JAMES B. TREFETHEN, JACK C. CULBREATH, WERNER O. NAGEL, AND JOSEPH J. SHOMON, Chairman.

Cooperative Relations with the American Fisheries Society

This committee explored cooperative relations with the American Fisheries Society through correspondence and a meeting with the Executive Secretary Committee of the Fisheries Society on December 6 and 7, 1960 in Toronto, Canada. The presidents of both Societies attended this meeting. R. E. McMullen served as proxy for Justin Leonard.

The discussion was objective and cordial. Following the joint discussion, each committee met independently to prepare a written statement concerning a suggested course of action. These statements were reviewed in a closing joint meeting. The statement of our committee follows and constitutes the substance of our report.

"Although a great deal in leadership could be achieved through some future alliance of the two societies, it is apparent that at this point, collaboration should be limited to the area of more economically handling the business affairs of the two societies. The work load of the respective secretarial offices is presently such that it does not appear favorable that a single executive secretary could handle the work of both Societies. It may, however, be possible to effect some economies by developing a close working relationship between the secretarial offices. It is suggested that to this end, and to the end of ultimate understanding, that the two societies collaborate wherever feasible in the sharing on an equitable basis of business services and in efforts to provide leadership in wildlife conservation affairs and further in efforts to develop a high level of competency and respect for fish and wildlife management. That these objectives may be implemented, we recommend that: (a) our respective secretaries be directed to consult with one another to determine and put into effect, efforts which are mutually beneficial in conducting the business affairs of the two societies; and that they report annually to the respective societies of the progress made and recommend action for future cooperative effort: and (b) that permanent parallel committees of the two societies concerned with joint efforts be established, which committees shall be charged with holding at least one joint meeting each year and of preparing a joint report to the two societies concerning matters of mutual interest."—Respectfully submitted, JUSTIN LEONARD, WINSTON MAIR, AND CHARLES A. DAMBACH, Chairman.

Economic Losses Caused by Vertebrates

This is the second year that this committee has been in existence. It was formed as the result of action taken by the National Academy of Sciences–National Research Council's Agricultural Board, who recognized that wildlife and other competitors of agriculture were important to the economy of the whole country. They further realized that information now available on such losses is based largely on estimates and these estimates, while useful, are recognized as being inaccurate in many cases and in many instances based on no reliable data. The Agricultural Board appointed a Committee on Agricultural Pests which in turn formed a number of subcommittees including one on Vertebrates, which was in existence from August 1958 to November 1960.

One of the primary objectives of the Subcommittee on Vertebrates was to stimulate leadership in this field in existing scientific organizations, in particular The Wildlife Society. C. A. Dambach's suggestions, when he appointed the first Wildlife Society Committee on Economic Losses Caused by Vertebrates in 1959 with Donald A. Spencer as Chairman, included the following three points.

1. "That it encourage studies within the profession to measure objectively economic losses caused by vertebrates. It seems to me that there has been a great deal of reluctance on the part of the student advisors to undertake these studies. This will be difficult to overcome but I believe that through consistently suggesting problems to research advisors that the idea will gradually take hold. The committee might well give consideration to means whereby such studies would be stimulated. It might, for example, propose and seek support for the establishment of one or more fellowships which would enable the graduate students to pursue research in this area or it may propose and give support to regional or national studies involving the participation of a number of mature research workers.

2. "That it encourage exchange of information between the many groups interested in vertebrates and members of The Wildlife Society which will lead to an understanding at a high level of the problems involved in coping with economic losses

caused by vertebrates, keeping in mind, of course, that the major concern of the Society at the moment is that of encouraging studies leading to the determination of the significance of such losses.

3. "The third and probably most important suggestion is to devise ways of keeping the wildlife profession informed on the subject so they will exercise good judgment in their own field of research and management work and especially in dealing with other interested groups."

In appointing the Committee for 1960, E. L. Cheatum provided the following comments regarding our responsibilities.

"The importance of the subject of wildlife nuisance control is growing rapidly and there are important areas of cross-purpose among both public and private groups and agencies which are administrative headaches to say the least.

"I feel part of this trouble comes from an inadequate dissemination of information among responsible agencies. Where poor coordination of action programs occurs, much of it may be due to lack of a common information base. Can we as a Society pull the pertinent information together on this subject and provide the guidelines for its use which would help bridge these conflicts?

"As pointed out in your Committee's report last year, we need to stimulate more research on control methods, selective ones being in greatest need. Our expressed concern should be not only directed to national agencies, but to state agencies as well."

What is the problem then that the Committee is charged with resolving? Prior to the advent of the European, all of United States was truly a wild land—free from the pressures of today's expanding human population with its controversial land-use quandary. But as the number of people continues to increase, the conflicts between man and wild vertebrates also become more frequent, since man is forced to continue to alter the natural scheme of things. This means that he must learn how to modify or manage the complex interplay of the life of all organisms within any area (balance of nature) in a harmonious manner that not only serves his immediate advantage but does so in a way that preserves as much of these resources as possible for posterity.

As long as the human population continues to boom in the United States, the farmer, the rancher, and the timberman will, out of necessity, have to produce more food and fiber from the land. To accomplish this, better ways must be found to protect crops from destruction by animals, for the producers can no longer afford the crop losses suffered by their forefathers, who sometimes even suffered famine and death from these causes. To obtain an increase in production from the land, farming methods must become further specialized even though the resulting extreme modification of the environment often causes the local elimination of certain species of vertebrates while others become troublesome.

When man attempts to farm land, he must bring about changes in the plant and animal relationships that often completely upset former balances. Such habitat modifications may allow some vertebrate animals to become more numerous. And even though a farmer is willing to share his crops with wildlife to some degree, he and the rest of us cannot afford this sharing if a species finds the new habitat conditions so favorable that it becomes too numerous and causes serious economic loss.

One important aspect of the steadily increasing demand for more food and fiber from the land is an assessment of the losses to agriculture, forestry, range management, and related industries that result from conflicts between wildlife and man. If serious vertebrate-caused losses are not prevented, it means that more land must then be brought under intensive management.

Domestic rats and mice, and field rodents are credited with the greatest economic damage, but losses from birds, rabbits, other game animals, and predators frequently may be even more serious. Reliable data are required if we hope to resolve the problems of where and when controls are desirable and the nature and extent of the management methods to be used. Also, it is necessary to consider carefully the ecological factors involved when agricultural pesticides are applied, to make sure, in the end, that they do more good than harm as far as all values are concerned. Losses and nuisance factors are frequently compensated by esthetic, sporting, and other beneficial values of wildlife.

An analysis of the subject of losses caused by vertebrates in the United States has uncovered some basic problems. If conservation, sporting, recreational, and economic interests in vertebrates are to be harmonious, much more research on losses caused by vertebrates and methods of overcoming these losses is required from individuals, organizations, and agencies. Better lines of communication are needed between the individuals engaged in research in this field, which involves many disciplines. Many urban citizens need a more enlightened outlook on man's relationships with wildlife, for ultimately the consumer pays the bill both in money and resources for losses caused by vertebrates.

An effort should be made to obtain a more objective treatment and training on the subject of wildlife and resource management in public education and school programs, giving adequate attention to wildlife damage problems as well as stressing the esthetic and beneficial values. The need for foundations, industry, and research agencies to work together in giving financial aid in this area should be publicized.

Wildlife control requires an ecological—not primarily chemical—approach, and leadership in this field should be assumed by The Wildlife Society and graduate schools. Through student guidance, scientific meetings, and THE JOURNAL OF WILDLIFE MANAGEMENT, all concerned should strive to de-

velop better methods of controlling troublesome vertebrates in a manner that will accomplish the desired effects with a maximum of safety to man and forms of life beneficial to him. The Society and schools should provide needed technical advice and guidance in this segment of environmental health and welfare by developing methods of critically evaluating both the direct and indirect effects of losses and control efforts and by developing and stimulating new research to obtain factual information as a basis for sound guiding principles and policy determinations in this area. Professional guidance is imperative to implement rational thinking in the field of wildlife damage control and to help us understand the ecological changes that are occurring. If The Wildlife Society membership wholeheartedly wishes to have this organization encompass the problems of vertebrate damage from such animals as rodents, moles, bats, rabbits, and other mammals, as well as many species of songbirds and game birds that at times also become troublesome, it must declare its intentions now. Otherwise, some new organization is sure to evolve in the near future, since one of the major problems in the field of vertebrate control is the lack of adequate lines of communication between research personnel and other workers in this field of endeavor.

Workers in the field of vertebrate damage control need a strong organization that can speak for them in matters concerning their welfare. They need an organization that can speak in behalf of the membership on matters which concern local, national, and public affairs. An organization is needed to keep the public informed about wildlife damage control to help overcome the strong emotional controversies that result from ignorance about the true role of controls. With such organization backing, lines of communication can then be established between workers, and this will result in a directed effort toward improved professional service including improved standards of training and performance. The Wildlife Society should represent this large group of individuals or they may come together on their own, and perhaps forever remain separated from The Wildlife Society. To prevent this from happening The Wildlife Society should establish a Wildlife Damage Control Section, with its Chairman having Council status. Whether or not to establish such a section is the problem that the current Wildlife Society Council must resolve. And to achieve a solution, they must first decide whether "wildlife" includes all mammals and birds or whether the Society's interpretation of "wildlife" is to be restricted to game and game-like animals.

Examples

A few examples of the type of areas where The Wildlife Society should take leadership, if a Wildlife Damage Control Section is established and the term wildlife is to include more than just game and game-like animals, include the following:

1. Overcoming the opposition of educational institutions to doing research on wildlife damage problems and giving prestige to the words control and damage.
2. Development and standardization of techniques for measuring losses and values and preparation of uniform forms for reporting such data.
   A. Physical losses should be expressed in terms of yield or quality rather than merely monetary loss.
   B. Categorization of losses by kind and age of vertebrate and/or crop involved as to type of value, damage, degree of loss, frequency of occurrence, general or localized, locality, season, and other pertinent ecological facts.
   C. Classification of vertebrate-caused losses as to crop, forest, soil, water (domestic and irrigation), stored crops, recreation, fish and game, buildings and equipment, homes, nuisance, and human and livestock diseases.
   D. Listing of and consultation with all local agencies and organizations which might be able to either provide precise data on economic losses or assist in obtaining it.
   E. Categorization of "losses" as to whether they include losses with respect to potential full yield, control expenses, value of game and recreation, etc.
   F. Determination of what degree of economic losses by vertebrates can normally be tolerated in the various situations.
3. Listing of present control methods and determining their adequacy, their relationship to beneficial wildlife; their cost; the need for better methods; where repellents are adequate; where a reduction in animal density is indicated; the practicality of attempting complete protection to the crop; how much of different crops could be saved if better methods of control were available and if present methods were utilized to better advantage; and when and with what crops it is currently impossible to control troublesome wildlife or where such controls would destroy other interests of greater value.
4. The Society should point out the hazards of reductional programs that simultaneously involve millions of acres, but it should give every attention possible to acceptable solutions of localized problems. It should move to sponsor research that aims at tools to avoid animal damage, so that reductional controls are used only when there is no other recourse. For example, the Society should:
   A. Develop better means of controlling pocket gophers, meadow mice, moles, jack rabbits, ground squirrels, and other field rodents.
   B. Attempt to develop new materials and techniques to solve bird depredation and bird nuisance problems.
   C. Work with various agencies in developing more efficient means of controlling domestic rodents.
   D. Investigate the use of various intensities

and frequencies of sound in the control of mammals and birds.

E. Develop means of controlling miscellaneous predators and noxious animals.

F. Search for better and safer poison baits and repellents that can be used by the general public.

5. Investigate predator-prey and pesticide-wildlife relationships.

6. Assist organizations and agencies working in vertebrate control by conducting demonstrations of control methods, techniques, equipment, and materials.

7. Determine whether the vertebrates concerned are more numerous or less plentiful as the result of man's altering of the environment and investigate the feasibility of habitat manipulation as a means of solving such animal-damage problems.

8. Publish review articles on methods of controlling different species.—Respectfully submitted, W. ROBERT EADIE, JAMES O. LEE, WILLIAM G. LEITCH, WELDON B. ROBINSON, DONALD A. SPENCER, AND WALTER E. HOWARD, Chairman.

Comment by The Wildlife Society Council.—"The Council is sympathetic to the problems brought to its attention by the Committee on Economic Losses by Vertebrate Animals. It recognizes that this subject is a matter of proper concern to the Society since the Society's concept of wildlife encompasses animals which may be harmful as well as all other vertebrate forms of animals in the wild. The Council is not in a position to act at the present stage of Society development in the establishment of a section concerned primarily with the problem of animal control. The Council wishes, however, to encourage through the Committee such activities as enhance the interest of that segment of the membership concerned with animal control problems, and to give, through the Committee, professional leadership in this area of concern. It wishes to encourage the Committee to further research, to exchange information, and to foster public understanding concerning this area of interest through THE JOURNAL and NEWSLETTER of the Society, through meetings conducted under the sponsorship of the Society and through correspondence of the Committee.

"The action of the Council at the March 5th meeting in encouraging local chapter organization indicates the Society's continued interest in evolving means of meeting the needs of its membership. Some further modification of the organizational pattern may be necessary as special areas of interest develop. These, like that of the animal control group, need further study before action of the kind recommended by your committee can be taken." (Prepared by Charles A. Dambach for the Council.)

Fisheries Publication Award

Kenneth E. F. Watt, Ontario Department of Lands and Forests, receives the Fisheries Publication Award for his *Studies on Population Productivity II. Factors Governing Productivity in a Population of Smallmouth Bass* (Ecol. Monog. 29: 367–392, Oct. 1959).

The runner-up in the contest was Edward H. Brown, Jr., whose *Little Miami River Headwater Stream Investigation* was published as a separate report by the Ohio Division of Wildlife in 1960.

The selections were made from 11 papers nominated by the committee.—Respectfully submitted, OLIVER B. COPE, WELDON LARIMORE, W. E. RICKER, SAUL SAILA, JOHN S. GOTTSCHALK, Chairman.

Professional Training and Employment

Early in 1961, the committee sent a questionnaire to a randomly selected 11 percent of the Society's membership in order to shed some light on the academic training of our members and the relationship of this training to age, salary level obtained, and type of employer. For the purpose of this study, "professionally employed" members were considered to be those 84 percent of our respondents who said that they were professionally engaged in fishery or wildlife management or in general conservation work. This definition may indeed include some that come within the category of "subprofessionals," and in our report the definition excludes those men professionally employed in fields like forestry and range management. The 215 men who answered the questionnaire constitute 7.2 percent of the Society's membership; another 0.2 percent could not be reached because of an obsolete mailing address. In our discussions below, it should be recognized that statistics cited for our profession and for the various types of employers hold only for those who are members of The Wildlife Society and that the nonresponse of 35 percent of those initially contacted by the committee may involve a potential prestige bias in our results that we did not attempt to analyze.

Age Distributions.—Among all our respondents, 23 percent were in their twenties, 35 percent in their thirties, 28 percent in their forties, 11 percent in their fifties, and 3 percent in their sixties and seventies (Table 1). Among those "professionally" employed as defined above, these percentages were 16 for those in their twenties, 38 in their thirties, 33 in their forties, 10 in their fifties, and 3 in their sixties and seventies. The rather sharp drop among these men after age 50 presumably reflects the rapid recruitment of trained men that was initiated in the fish and wildlife field in the mid-1930's. A slight drop among those aged 35–39 may represent a sampling error or a drop in recruitment back around 1945.

Academic Degrees.—Among all our respondents, 54 percent held an advanced degree; among those in our "profession," 48 percent (Table 1). There is a conspicuous postponement in onset of employment according to degree received, with no Ph.D.'s among our small sample of respondents employed below age 30. Among the 71 finding professional employment at the B.S. level, 79 percent were with

TABLE 1.—RELATION OF AGE TO ACADEMIC DEGREE AMONG 215 MEMBERS

STATUS	STUDENT[1]	NO. "PROFESSIONALLY" EMPLOYED (AND DEGREE)					OTHERS[2]	TOTALS	PERCENT
		None	B.S.	M.S.	Ph.D.	Subtotals			
AGE (years)									
20–24	4	—	4	—	—	4	—	8	4
25–29	9	—	14	11	—	25	7	41	19
30–34	—	—	14	15	9	38	4	42	20
35–39	—	—	13	10	7	30	3	33	15
40–44	—	1	12	13	8	34	—	34	16
45–49	—	2	4	11	8	25	2	27	13
50–54	—	1	7	1	4	13	3	16	7
55–59	—	1	1	2	2	6	1	7	3
60–64	—	—	2	—	2	4	1	5	2
65–69	—	—	—	—	1	1	—	1	—
70–74	—	1[3]	—	—	—	1	—	1	—
Totals	13	6	71	63	41	181	21	215[4]	99
Percent	6	3	33	29	19		10	100	
Mean age (years)		53.8	37.1	37.7	43.2	39.2	38.0		
EMPLOYER									
State or province[4]		3	56	44	7	110	0.5	110.5	54
Federal		1	13	13	12	39	2.5	41.5	21
College or univ.		—	—	2	19	21	6	27	13
Private and misc.		2	2	4	3	11	12	23	11

[1] Includes 1 candidate for B.S. degree, 7 graduates with a B.S., 4 more with an M.S., and 1 M.S. recipient now in military service. Part-time students were not included here.

[2] Eleven have B.S. degree, 6 have M.S., and 4 have Ph.D.

[3] Degree not indicated by one respondent.

[4] Includes (here and in subsequent tables) one man employed at the county level.

state or provincial agencies, and 18 percent with federal agencies. Among the 63 having an M.S., about two-thirds were employed by state or provincial agencies. Among the 41 Ph.D.'s almost one-half were, as one would expect, employed by colleges and universities.

Type of Employer.—Among our 181 professionally employed respondents, the men employed at the state and provincial level (Table 2) tended to constitute the younger men among those we questioned; their ages averaged 3–3.5 years below the ages of those in the federal and college groups, and their salaries averaged about $2,000 less. Federal salaries and mean age were similar to those at the college and university levels despite the differences in academic degrees among those representing each type of employer.

Salary Levels.—In general, it appears that among our professionally employed respondents, B.S. recipients reach the same mean salary ($6,900) as M.S. recipients by the time they are 40 years of age (Table 3). After this point, professional advancement of these two groups no longer seems to be influenced by academic training; and administrative ability becomes more important. Salaries of Ph.D. recipients follow this trend to a lesser degree, only one-sixth of these being influenced by salary patterns at the state and provincial level.

TABLE 2.—AGE DISTRIBUTION ACCORDING TO TYPE OF EMPLOYER

AGE IN YEARS	NUMBER "PROFESSIONALLY" EMPLOYED				TOTALS	PERCENT
	State or Province	Federal	College or Univ.	Private		
20–24	4	—	—	—	4	2
25–29	18	7	—	—	25	14
30–34	22	5	6	5	38	21
35–39	19	7	4	—	30	17
40–44	25	4	5	—	34	19
45–49	12	9	3	1	25	14
50–54	7	3	2	1	13	7
55–59	2	2	1	1	6	3
60–64	1	1	—	2	4	2
65–69	—	1	—	—	1	—
70–74	—	—	—	1	1	—
Totals	110	39	21	11	181	99
Percent	61	22	10	6	99	
Mean age	37.6	41.0	40.6	46.5	39.2	

TABLE 3.—SALARIES OF "PROFESSIONALLY" EMPLOYED MEMBERS

ACADEMIC DEGREE REPORTED	AGE IN YEARS	NUMBER REPORTING WITH SALARIES TO NEAREST $1,000													TOTALS	MEAN SALARY[1]
		$4	5	6	7	8	9	10	11	12	13	14	15	15+		
None	40–44			1											1	
	45–49		1			1									2	
	50–54			1											1	
	55–59				1										1	
	70–74												1[2]		1	
	Totals		*1*	*2*	*1*	*1*							*1*		*6*	*$7.8*
B.S.	20–24	1	3												4	4.8
	25–29	2	8	3	1										14	5.2
	30–34		5	7	1	1									14	5.9
	35–39		2	6	1	3	1								13	6.6
	40–44		3	3	2	2	1		1						12	6.9
	45–49			1		2						1			4	9.0
	50–54				2		1	4							7	9.0
	55–59						1								1	
	60–64			1								1			2	
	Totals	*3*	*21*	*21*	*7*	*8*	*4*	*4*	*1*			*2*			*71*	*6.7*
M.S.	25–29	1	6	3	1										11	5.4
	30–34	1	5	4	4	1									15	5.9
	35–39			1	6	3									10	7.2
	40–44		3	2	1	7									13	6.9
	45–49			2	2	1	1	1		2				2	11	9.3[3]
	50–54						1								1	
	55–59					1		1							2	
	Totals	*2*	*14*	*12*	*14*	*13*	*2*	*2*		*2*				*2*	*63*	*7.2*
Ph.D.	30–34			2	4	1	1	1							9	7.4
	35–39			1	1	2	2	1							7	8.1
	40–44			1	2	3	1			1					8	8.1
	45–49				1		3	1	2		1				8	9.9
	50–54					3		1							4	8.5
	55–59							1		1					2	
	60–64						1							1	2	
	65–69								1						1	
	Totals			*4*	*8*	*9*	*8*	*5*	*3*	*2*	*1*			*1*	*41*	*8.8*
Grand totals		5	36	39	30	31	14	11	4	4	1	2	1	3	181	$7.4
Percent		3	20	22	17	17	8	6	2	2	–	1	–	2	100	
State or prov.		4	33	30	15	19	4	3	1	1					110	$6.4
Federal		1	2	5	10	5	6	4	2	2		1		1	39	8.3
Coll. or univ.			1	2	4	5	3	3	1	1	1				21	8.5
Private				2	1	2	1	1				1	1	2	11	11.3

[1] Annually; to nearest $1,000.
[2] Involves one respondent who did not answer query re degree attained.
[3] Omits one salary over $20,000 where respondent's income was partly in other fields.

Attendance at Conferences.—Among our repondents, no question elicited so many comments as the queries on conference attendance. Among those professionally employed in our field, 74 percent reported attending two or less North American Wildlife Conferences in the past 10 years. Salary levels were importantly associated with attendance: Those attending no meetings averaged $6,200 per year; one meeting in 10, $6,800; two meetings in 10, $7,500. Those attending seven or more averaged over $10,000. Complaints regarding nonattendance emanated from federal employees, state and provincial employees, and from college teachers. In one state, the Bureau of Personnel has ruled that employees going to out-of-state conferences without their expenses paid must do so on vacation time even when they are reading papers there. One college teacher complained that the timing of the conference continuously prevented him from attending. In general, the failure of civil service systems to help their personnel to attend national meetings appears to be a real source of intellectual frustration among those who consider themselves professionally employed in our

TABLE 4.—ATTENDANCE AT NORTH AMERICAN AND REGIONAL CONFERENCES BY PROFESSIONALLY EMPLOYED PERSONNEL

Conference / Employer	North American State or Province	North American Federal	North American College or University	North American All Agencies[1]	Regional
Men Reporting	110	39	21	181	181
No. of Last 10 Conferences Attended			Percent Attending		
0	48	33	43	43	22
1	18	26	10	18	18
2	13	10	19	13	14
3	6	8	5	7	7
4	5	8	–	5	8
5	1	3	10	2	7
6	3	3	5	2	4
7	2	5	–	3	5
8	4	3	5	4	3
9	–	–	5	1	5
10	1	3	–	2	8
Totals	101	102	102	102	101
Mean no. attended	1.2	2.2	2.3	1.9	3.4

[1] Including 11 employed by private agencies.

field. Attendance at regional wildlife conferences is much better than at the North American one (Table 4), as one would expect.

Other Committee Business.—At the Council's request, this committee did not run an employment desk at the annual meeting. It did attempt to assist in developing an employment column in WILDLIFE SOCIETY NEWS. Although over 70 potential employers were contacted by the committee in January, the February issue of the NEWS carried only a few notices. This experiment does not seem to hold a great deal of promise at this time, but it undoubtedly should be continued for one more year.

During the 1961 North American Wildlife and Natural Resources Conference, the committee sponsored a symposium on Wildlife Management in Europe and the Near East. This meeting was chairmanned by President E. L. Cheatum, with G. A. Swanson serving as discussion leader and 56 persons attending. We are much indebted to the participants at this interesting meeting: M. M. Alexander, H. G. Cumming, P. L. Errington, E. H. Graham, F. M. Packard, T. J. Peterle, D. H. Pimlott, L. W. Swift, and W. P. Taylor.

The attention of our membership is called to the fine Salary Schedule Survey that the National Wildlife Federation brought up-to-date in October 1960. Contact with Professor E. W. Foss of Cornell was maintained by the committee relative to certain changes in the U. S. Department of Labor's Dictionary of Occupational Titles; this will need to be followed up by our successors next year.—Respectfully submitted, F. M. BAUMGARTNER, D. A. BENSON, J. L. BUCKLEY, C. H. D. CLARKE, D. E. DAVIS, W. A. FULLER, R. E. GRIFFITH, W. D. KLIMSTRA, D. A. POOLE, H. D. RUHL, T. G. SCOTT, A. M. STEBLER, E. A. WALKER, AND J. J. HICKEY, Chairman.

Terrestrial Wildlife Publication Award

The Committee considered a rather large group of publications for the 1960 publication award. The final decision of the Committee was a joint award to two publications in the wildlife field. One is the work of Helmut K. Buechner entitled *The Bighorn Sheep of the United States,* published by The Wildlife Society as WILDLIFE MONOGRAPHS No. 4. The second publication is co-authored by Robert S. Dorney and Cyril Kabat, *Relation of Weather, Parasitic Diseases, and Hunting to Wisconsin Ruffed Grouse Populations,* Technical Bulletin No. 20, Wisconsin Conservation Department. Robert Dorney, a member of this committee, was not included in the final balloting when it was apparent that his publication was a contender. The Wisconsin publication is the result of 10 years of publication research and a thorough analysis of grouse population. The mountain sheep monograph is much more than a compilation of other research results. It blends a review of all mountain sheep work in the United States together with the author's own experience and extensive studies.—Respectfully submitted, MAURICE F. BAKER, JAMES F. BENDELL, ROBERT S. DORNEY, C. W. SEVERINGHAUS, AND KENNETH E. HUNGERFORD, Chairman.

Wildlife Techniques

A total of 2,070 copies of the *Manual of Game Investigational Techniques* was multilithed for the Society by Edwards Brothers of Ann Arbor, Michigan. This Society publication was distributed through the offices of the Virginia Cooperative Wildlife Research Unit, beginning in mid-May of 1960. The first printing was sold by January 1961 and Council authorized a second printing of 1,000 copies. This second printing (with only very minor corrections) will be available for distribution

by mid-March of 1961. Should demand justify, the *Manual* will be revised completely prior to any additional printings. Therefore, the Committee would welcome from all members of the Society suggestions for improving the *Manual* prior to any revision.

President Cheatum appoined Lowell Adams and Frank Craighead to the Wildlife Techniques Committee with the specific assignment of assemblying information on the radio-tracer technique for studying animal populations. This assignment also included establishing lines of communication between the individuals now working with this technique. Adams compiled a newsletter and, in January of 1961, distributed this newsletter to some 30 individuals known to have an interest in this subject. An informal meeting of personnel interested in telemetering and its use in wildlife studies will be held at the 1961 Wildlife Conference.—Respectfully submitted, LOWELL ADAMS, FRANK C. CRAIGHEAD, IAN MCT. COWAN, DAVID E. DAVIS, ANTOON DE VOS, ALEXANDER C. MARTIN, HORACE F. QUICK, RICHARD D. TABER, AND HENRY S. MOSBY, Chairman.

BRIEFER ARTICLES

NARCOSIS OF MOOSE WITH NICOTINE[1]

Robert A. Rausch[2] and Ralph W. Ritcey

U. S. Fish and Wildlife Service and Alaska Department of Fish and Game, Juneau, Alaska; and Department of Recreation and Conservation, Victoria, British Columbia

This paper reports the results of the use of the Palmer Cap-Chur equipment and the effects of nicotine on moose in two winter field trials, one in south-central Alaska, 1957 and 1958, and the other in Wells Gray Park, British Columbia, 1959. The carbon dioxide-propelled syringe (Crockford, *et al.* 1958. Vet. Med., 53:115–119) did not function satisfactorily under extreme winter conditions, particularly in south-central Alaska. The effects of nicotine on moose were widely divergent in the two studies; mortality was excessive in the British Columbia study.

Details of pharmacological action of nicotine and results of the use of nicotine salicylate on deer have been given previously (Crockford, *et al.* 1957. J. Wildl. Mgmt., 21:213–220). Since the effects of nicotine in achieving paralysis of moose are similar to those reported for nicotine salicylate with deer, the symptoms are not discussed in detail.

The two trials were carried out independently with the results of the Alaska trials not being known by the junior author until his work was well under way.

EQUIPMENT

The Palmer Cap-Chur-Gun proved sufficiently accurate for field use to approximately 30 yd. Beyond this distance, the trajectory of the loaded darts is too curved to allow accurate shooting unless the range is known. The trajectory also varies as a result of pressure changes of the carbon dioxide gas within the gun because of severe temperature fluctuations. A 20 percent power loss is possible in the temperature range occurring during trials (60° F. to –30° F.)

The ejecting agent supplied with the equipment to force the drug from the syringe was found to be slow and unreliable at low temperatures. It was replaced by Bromo-seltzer or Alka-seltzer. Both of these gave more rapid delivery of the drug, but in extreme cold weather drug delivery was still sometimes incomplete. In temperatures well below freezing it was necessary to keep the syringe components, water and nicotine,[3] warmed in some manner; body heat was sufficient. Complete injections were obtained, in most cases, when syringe components were artificially warmed. Malfunctions of gun and syringe were considered major disadvantages of the equipment for winter use in Alaska.

Tissue damage resulting from hits by the darts was minor when collared needles were used and did not remain too long in the flesh. Barbed needles and collared needles which did not drop from the moose within a few minutes caused slightly more damage when muscular action churned the needle about in the flesh. Edema resulting from dart hits was not serious.

METHODS

In the south-central Alaska areas (Matanuska Valley and Anchorage) where the Alaska portion of this project was conducted, moose are not par-

[1] A joint contribution of Federal Aid in Wildlife Restoration Project W-3-R Alaska, U. S. Fish and Wildlife Service, Alaska Dept. of Fish and Game; and British Columbia Dept. of Recreation and Conservation.

[2] Present address, Alaska Dept. of Fish and Game, Box 1027, College, Alaska.

[3] Complete details for loading the syringe are furnished with the equipment.

TABLE 1.—MOOSE INJECTED WITH NICOTINE UNDER NATURAL CONDITIONS, SOUTH-CENTRAL ALASKA

Narcosis	Sample Size	Dosage (mg./lb.)		Minimum to Maximum Narcosis		Known Mortality
		Range	Average	Range	Average	
Complete	8	4.5–6.4	5.0	2.5–6.5	4.7	0[3]
Partial[1]	6	3.3–4.7	3.6	4.0–9.0	5.6	0
Unsuccessful[2]	3	2.9–3.8	–	–	–	0
	17					0

[1] Some paralysis, but animals were not sufficiently immobilized to handle.
[2] No apparent effect.
[3] A female fell from a cliff and fractured her neck. A female captive calf succumbed when administered 4.5 mg./lb. of body weight.

ticularly wary during the winter, and can be stalked successfully. The moose were located by driving along the roads until one was sighted. The animal was then injected from the vehicle or after stalking afoot. This technique did not unduly alarm the moose; many of them, after having been injected, continued to browse or merely stared at the intruder.

Because the scope of the project was purely investigational, none of the animals were restrained in any way. Those that were sufficiently immobilized were ear-tagged, measured, and observed until recovery was apparent.

In British Columbia, stalking proved unproductive as a hunting method. Moose were generally wary and usually would not tolerate approaches to within the effective range of the equipment. However, the investigator, using snowshoes, and usually with the aid of a dog, was able to run down moose in deep snow. When the dog had sufficient maneuverability, it could bring moose to bay quickly. Two dogs were more effective than one for holding moose at bay, though an aggressive dog could do it alone. With the moose occupied in fighting the dog it was possible to approach closely and shoot the darts into the hindquarters.

RESULTS

Forty moose were injected with nicotine within the two study areas, 17 in south-central Alaska and 23 in Wells Gray Park, British Columbia. The results are given in Tables 1 and 2.

In south-central Alaska, none of the 16 unrestrained animals injected with nicotine are known to have died from the effects of the drug. Two moose narcotized under adverse weather conditions are known to have survived for nearly a year. A mature cow, accompanied by a calf of the year, was tagged in December 1957, when the temperature was –15° F. This cow, again accompanied by a calf of the year, was killed in November 1958. A mature bull tagged in January 1958, when the temperature was –20° F., was killed by a hunter the following November.

One cow died when she fell from a cliff and fractured her neck during the excitatory phase of narcosis. A captive calf died within 5 min. after receiving a dosage of 4.5 mg./lb. of body weight; subsequent autopsy showed that the calf was suffering from extreme malnutrition.

The efficiency of nicotine, based on the relative degree of paralysis induced in the 15 animals that are believed to have survived the test in Alaska, is as follows: 40 percent complete paralysis; 40 percent partial paralysis, and 20 percent no paralysis. In the Alaska experiments, the degree of paralysis was apparently directly proportional to the dosage; dosages below 4.5–5.0 mg./lb. of body weight did not effect complete paralysis (Table 1). The occasional failure of the syringe to discharge its entire contents into the moose, particularly during cold weather, complicates interpretation of the data. Perhaps some of the instances of partial paralysis reflect equipment failure rather than drug failure.

In Wells Gray Park only four moose were immobilized sufficiently to be handled without ropes when sublethal dosages were given. All remaining moose had to be roped by the feet before they were sufficiently subdued to be ear-tagged. Pre-

TABLE 2.—MOOSE INJECTED WITH NICOTINE UNDER STRESS, BRITISH COLUMBIA

Narcosis	Sample Size	Dosage (mg./lb.)		Minimum to Maximum Narcosis		Known Mortality
		Range	Average	Range	Average	
Complete	10	2.1–12.5	3.9(2.9)[1]	3–70	27.4	6
Partial	8	2.0– 3.0	2.5	3–60	17.6	0
Unsuccessful	5	1.5– 3.3	2.3	–	–	0
	23					6

[1] Average excluding the one obvious overdose of 12.5 mg./lb. of body weight.

vious experience had shown that roping by the neck may kill moose through suffocation when regurgitated food is forced into the lungs. After being tied securely, the moose usually became quite docile. The restraint imposed by ropes seemed to reinforce the narcotic action of the drug.

Six deaths resulted from injecting the 23 British Columbia moose with nicotine (Table 2). One death resulted from an obvious overdose of the drug. The remaining dosages were within or below the range of those used successfully in Alaska (Table 1). The level of one lethal dose was insufficient to produce paralysis in four other cases. In five deaths occurring in the low-dosage range, two animals were in a state of extreme fatigue, two were moderately fatigued, and one was a fresh animal. All moose were in a state of excitement when injected and this stress was probably a contributing factor in the death of the moose which died after injection.

Only one of the six moose killed in British Columbia died rapidly. This was a mature cow, in good health, which received 3.6 mg. of nicotine per pound of body weight. All other deaths occurred more than 24 hours after injection of the drug. In every case the moose drastically lowered its food intake after injection, with at least one animal apparently dying from starvation. This animal, a mature bull, fed very little for 1 week after injection. On the seventh day he appeared weak, but made aggressive motions when approached. When thrown browse he engaged in displacement feeding. During the week following injection of the drug he defecated several times but urinated little or possibly not at all. When disturbed on the seventh day he voided a large quantity of urine. On the following day he again urinated freely after being encouraged to stand.

After the first week his food intake increased markedly, and 20 days after injection he appeared to be gaining weight and was obviously much stronger. When revisited 6 days later he was dead. Death occurred approximately 23 days after the drug was injected.

Three different supplies of nicotine, all from the Palmer Chemical Co., were used for the field test in British Columbia. The first appeared unsatisfactory, with recovery from the drug being uncertain at what were thought to be sublethal dosages. The second showed some improvement but failed to give complete narcosis in all cases. The third supply was used on only one moose, which was promptly knocked down and also showed rapid recovery.

Because of the desire to tag a large number of moose, it was necessary to leave some animals before they had fully recovered from the drug in order to capture others. All moose were later revisited to see whether recovery was complete.

DISCUSSION

Although the samples were small, the observed after-effects and subsequent mortality of injected moose were quite different on the two areas (Tables 1 and 2). The differences in the techniques employed in approaching and handling the animals are the obvious possible reasons for the much higher mortality in the British Columbia trials. All of the moose injected in British Columbia were excited and therefore under some degree of stress when injected. Fatigue also contributed to the stress, but one moose died that showed no fatigue at all. None of the Alaska moose were excited, fatigued, or in any way restrained before or after injection. If the drug qualities were similar in the two trials, then fatigued and excited moose have a lower tolerance to nicotine than do fresh and calm moose. In south-central Alaska, dosages which effected complete paralysis were, in most instances, from 30 to 100 percent greater than dosages used in British Columbia which resulted in death of moose.

Physical condition of the animal may also be a factor in determining its tolerance to nicotine. This was suggested by an experiment in Alaska with a captive calf in very poor condition that died within 5 min. after receiving what was considered a safe dosage.

Variation was noted in the effectiveness of three supplies of nicotine used in British Columbia, but the number of moose involved in each supply was too small to allow a conclusive statement of variation.

Although the difficulties encountered in using the equipment were largely overcome by keeping syringe components and drug warm, the carbon dioxide-powered equipment is not generally satisfactory for winter use, particularly under conditions encountered in south-central Alaska.

Nicotine was largely unsatisfactory as a narcotic agent when used on excited or fatigued animals. In most cases it failed to immobilize sufficiently to allow the animal to be safely handled. Further, the mortality of moose injected with the drug was much too high.

SUMMARY

Nicotine and the Palmer Cap-Chur equipment were tested on moose in two independent field trials in Alaska and British Columbia. In the British Columbia tests, where the moose were under stress, the mortality rate was excessive. Moose that are under stress or fatigued apparently have a lower tolerance to nicotine than do moose that are injected under natural conditions. The carbon dioxide-operated equipment did not function satisfactorily in extremely cold weather.

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COLLARS FOR MARKING MOUNTAIN HARES

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Although different types of collars have now been used to mark several species of wild mammals, it is important that the exploratory work of using such a method for each species should be fully reported. During a field study, collars of patent leather were used, among other methods, to mark mountain hares (*Lepus timidus scoticus*). As the mountain hare is a wary animal, living chiefly upon open heather-covered hillsides at an altitude of 1,000 ft. or higher, identifying marks need to be visible at long range. No marking of mountain hares has been carried out prior to the present study, and of other species of hares which have been marked, none occurs in open mountainous country where long-range identification is essential.

In this study, all hares caught were marked by pinning a serially numbered poultry wing tab inside the right ear of males and the left ear of females. These tabs were painted in bright colors or covered with "Scotchlite" or "Scotchcal" sheeting as an additional aid to short-range identification. Three other methods of marking were used: (a) a celluloid disc, 1 in., or 1¼ in. in diameter, secured to each side of the untabbed ear by a rivet similar to that described by Tyndale-Biscoe (1953); (b) a patent leather collar described later; (c) a brightly colored dye, usually Rhodamine B500.

Patterns on the discs, usually semicircles of "Scotchlite" or "Scotchcal" tape, give individual markings identifiable, under favorable conditions, with 10× binoculars, at 100 to 150 yd. The disc itself can be seen from 100 to 400 yd. away, depending on the color used and the light. The use of collars increases the distance at which marked hares can be detected to as much as 600 yd. This distance varies greatly with the position of the sun, color of the collar, and posture of the hare. White winter pelage provides better contrast, but the longer fur and denser coat conceal part of the collar. A loping hare extends its neck and reveals the collar, while the ears, being laid back, tend to hide the disc. Hares with collars can be more closely approached and the disc pattern examined. Because of the molts the dye normally remains visible for only a few weeks, but can be seen at 800 to 1,000 yd. when newly applied. From August 1957 through July 1960, tabs, collars, and dye were used on all hares caught except the small leverets. Discs were used from August 1958 onwards. This paper is primarily concerned with the efficacy of the collars.

I am grateful to G. M. Dunnet for advice during the preparation of this paper. G. H. Kelker, Utah State University, suggested several amendments to the original draft which have now been incorporated. Osmond and Osmond, Ltd. of Portsmouth made hare collars and suggested suitable materials. The Nature Conservancy made a grant towards the cost of this work.

Description of Collars

Collars are made from colored non-cracking patent leather, which is available in red, green, yellow, pale blue, white, navy, and black. For marking mountain hares, yellow is the most effective color, then red and green. Navy and black collars are indistinguishable in the field and difficult to see when the hare is in brown summer or autumn pelage; white collars are almost impossible to see when the hare is in white winter pelage. The color fades very little on exposure to light and weather; a collar, removed from a hare carcass and fastened to a fence at 1,500 ft. elevation, was only slightly faded 13 mo. later. Collars ⅞ in. or 1 in. wide proved most suitable. These are secured by an ordinary buckle, and a series of holes (the first 6¼ in. from the buckle and others at ⅜-in. intervals) permits individual fitting. The collars are adjusted so that a finger can be comfortably inserted between collar and neck. To minimize the size and weight of the buckle the collar is tapered at both ends (Fig. 1, *top*).

At first, individual patterns similar to those used by Ealey and Dunnet (1956) and Progulske (1957) were marked upon the collars in one of three ways: with quick drying enamel paint; with strips of colored plastic sheeting glued or sewn to the leather (Fig. 1, *top middle*); or with "Scotchlite" reflective tape (Fig. 1, *bottom middle*). The enamel had neither faded nor cracked on collars recovered up to 11 mo. after fitting, but glued-on plastic fell off, and sewn-on plastic made the collar too stiff. "Scotchlite," while giving good clear patterns, proved unsuitable because some hares scratched part of the symbols from their collars. In all cases the fur of the neck concealed part of the collar, making the marks difficult to see and unreliable as a sole means of identification.

As collars were being lost by becoming unfastened, or by being torn through by the hares at the narrow part near the buckle, a modified type of collar was devised. Strips of patent leather, of the same type, colors, and widths as before but 8¼ in. long, were punched with 3/16-in. holes at either end (Fig. 1, *bottom*) and secured by two or three leather workers' eyelets. (The eyeleteer can also be adapted as an ear punch for fitting discs.) These strip collars have not been marked with distinctive patterns, but simply with identifying numbers in case they are found lying on the hill

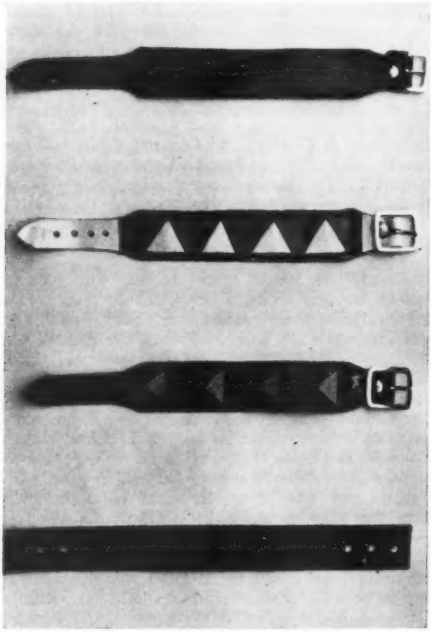

FIG. 1. Collars for marking hares. *Top*—Without individual marking. *Top middle*—Sewn-on plastic marking. *Bottom middle*—"Scotchlite" tape marking. *Bottom*—Strip collar with eyelets.

after a carcass has broken up or after being removed by a hare. Different colors are used for each sex and for each of three marking areas. Having no individual marking, this second type of collar identifies only classes of animals: recognition of individuals now depends upon the disc.

RESULTS

Trapping of hares was carried out at intervals of about a month, with gaps of up to three mo. owing to severe winter weather and other causes. Of 160 collars fitted over a period of 35 mo., 32 (20 percent) are known to have been lost either through faulty securing or removal by the hares. It is likely that hares which lose or remove their collars do so fairly quickly. Three collars found lying on the ground had all been shed within 5 weeks of fitting, and among 32 hares recaptured or shot which had lost their collars, 13 had done so within 3 mo. and 20 within 6 mo. Of 21 hares recaptured or identified with collars on, 15 had been wearing them for more than 3 mo., and 7 for more than 6 mo. Twenty-nine collars were recovered from dead hares, including those killed by hunters. Of these, 17 had been on more than 3 mo., and 10 for more than 6 mo.

The proportion of collars lost varied with the sex and age of the hare. Of 61 collars fitted to males, 6 (9.8 percent) were lost, and of 53 fitted to females, 11 (20.8 percent) were lost. I found no difference in behavior between the sexes to explain this difference, which is of doubtful significance. The higher proportion of collars lost by leverets, 15 out of 46 (32.6 percent), can be accounted for by collars which slipped from the head unfastened (some of these have been picked up in the study area), or by the necessarily loose-fitting collar which gave more purchase to a hare trying to scratch through it.

Among recovered collars, including those removed by hares as well as those taken from dead hares and collars changed experimentally, 9 out of 29 show some sign of scratching or more substantial damage; 7 were torn near the buckle, an area in which metal corrosion might weaken the leather. Some eyeletted strips have been lost, but it is not known whether through faulty securing or because the hares scratched through them. A recovered strip showed only slight damage by scratching, and this type (Fig. 1, *bottom*) of collar is considered to be more satisfactory than those fitted with buckles.

Collars do not appear to affect the hare's behavior or its relations with other hares. There is, however, much variation in the individual's tolerance to wearing a collar. One hare wore a collar (changed after 11 mo.) until it was killed 19 mo. later, while another removed three successive collars within 15 mo., and a third hare two in 5 mo. Other hares, which have had their collars changed on recapture, have worn collars continuously for totals of 10, 12, and 17 mo. respectively. During molts, fur sometimes accumulates inside the collar at the throat, but this does not make it uncomfortably tight. Because of the large number of modifications made to the collars, a detailed analysis of rate of loss, or of length of wear in relation to sex and age, might be misleading. Average an-

TABLE 1.—MINIMUM TIME DURING WHICH COLLARS WERE RETAINED BY MOUNTAIN HARES

	TIME IN MONTHS AFTER MARKING															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Hares recovered alive	5	1	0	4	2	2	1	0	0	1	3	2	0	0	0	0
Hares recovered dead	4	6	2	4	1	2	1	2	3	0	0	1	1	1	0	1
Total	9	7	2	8	3	4	2	2	3	1	3	3	1	1	0	1

nual hare mortality is high, of the order of 50 percent in various hare populations examined during the period of the study, a fact which limits the potential period of use of the collar. Relatively few hares, adult or juvenile, survive into the second year after marking, and fewer still into the third. In 1959, of 36 hares recovered dead, 28 (78 percent) were recovered within the first year after marking, 6 (17 percent) within the second year, and 2 (5 percent) within the third year. Only 1 of about 300 marked hares is known to have survived into the fourth year after marking.

Sight records of hares fitted with collars, but not identified beyond sex and marking area, have provided useful information on movements and sexual and aggressive behavior. The collars as described should be suitable for use on other hares (*L. timidus* and *L. americanus*), and, with slight modification, brown hares (*L. europaeus occidentalis*). A collar ⅝ in. or ¾ in. wide and 6¼ in. long might be suitable for rabbits (*Oryctolagus cuniculus*), which have much shorter neck fur.

Summary

A patent leather collar for marking mountain hares (*Lepus timidus scoticus*) is described. Although unsatisfactory as the only means of marking hares individually, collars have proved valuable in detecting, at ranges up to 600 yd., hares additionally marked in other ways. The use of collars of different colors for each sex and marking area can provide useful information on movements, and on sexual and aggressive behavior without identifying individual hares. During a period of 35 mo. at least 20 percent of the collars were lost. Hares vary greatly in their individual tolerance of collars.

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EFFECT OF TRAPPING ON ADRENAL ACTIVITY IN *SIGMODON*[1]

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Wildlife biologists commonly use live traps to study the population ecology of mammals. This technique is useful because it makes possible an estimation of (1) population density, (2) mortality and natality, (3) weight change or growth, and (4) distribution patterns. When using live traps, the investigator assumes that trapping an animal repeatedly does not materially change its physiology or behavior. However, in the study of populations by live-trapping, the mammal is usually held in the trap for several hours, perhaps subjected to marked fluctuations in temperature, to hunger, and, when released from the trap, to physical injury if the animal is marked by clipping off one or more toes. A number of workers, including Selye (1950), have presented evidence that extreme heat or cold, reduced food-intake, and physical injury result in increased secretion of hormones by the adrenal cortex. Presumedly the increased adrenal activity aids the animal in adapting to the stress conditions. The present study was initiated to determine if the adrenal gland was affected by live-trapping in a population of cotton rats (*Sigmodon hispidus*) living in their natural habitat. Changes in the width of the zona fasciculata (the middle zone of the adrenal cortex), in quantity of lipid in the cortex, and in fresh adrenal weight were used as criteria of adrenal gland activity.

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Harry Kent, University of Georgia, materially assisted this study by his suggestions regarding endocrinological problems, by critically reading the manuscript, and by providing the materials used in the histological study of the adrenal tissue. E. P. Odum, University of Georgia, has also aided the study through his suggestions and comments, and James Carmon, Institute of Experimental Statistics, University of Georgia, suggested and carried out the analysis of adrenal-body weight relationships on the IBM 650 computer.

Methods

In October 1958, a wild population of cotton rats was trapped for 8 days and then snap-trapped for 6 days. Since the snap-trapped sample included rats not previously live-trapped as well as those live-trapped from one to seven times, it was possible to study the relationship between adrenal cortex activity and capture in live traps. The 1958 experiment was repeated in October 1959 in the same field. In October of both years, the population was composed of juveniles, adult males, and pregnant as well as non-pregnant females.

Cotton rats are most active at dusk and dawn; therefore, to assure that few animals would remain in the traps longer than 4 hours, both live and snap traps were examined at 8:00 a.m. and 8:00 p.m. daily. The traps were baited with a liberal supply of oats and corn. During the live-trapping program,

TABLE 1.—A COMPARISON OF THE RATIO OF WIDTH OF THE ZONA FASCICULATA (Z.F.) TO THE ZONA FASCICULATA PLUS ZONA GLOMERULOSA (Z.G.) IN LIVE-TRAPPED AND NON-LIVE-TRAPPED COTTON RATS

Classification	Number of Adrenals	Mean Width		Ratio
		Z.F. (mm.)	Z.F. & Z.G. (mm.)	Z.F. / Z.F. & Z.G.
Live-trapped	27	0.345	0.380	0.908
Non-live-trapped	49	0.315	0.365	0.863

each rat was marked by clipping one or two toes per individual.

Dead rats collected during the evening sampling period from the snap traps were brought into the laboratory and frozen. The following morning these rats were thawed and examined along with those collected that morning. Each specimen was examined for toe-clipping marks, then weighed, aged (all rats over 70 g. were considered adult), sexed, and the reproductive condition noted. The adrenal glands were then removed, cleaned of fat, and weighed on an analytical balance. After weighing, the adrenals from the 1959 sample were stored in 4 percent formalin solution and were later sectioned with a freezing microtome.

The zona fasciculata was measured with a micrometer eyepiece on slides stained with haematoxylin, counterstained with eosin, and on others stained with Sudan III in propylene glycol. The quantity of lipid in the cortex was estimated in tissues stained with Sudan III. The intensity of blue-black color is proportional to the quantity of lipid in the tissue. A visual method of judging the intensity of the staining reaction was employed. First, the slides were examined and the range of color determined. Second, all slides were re-examined and placed in five categories, very dark, dark, medium, light, and very light. Third, the slides in each category were examined and rearranged if necessary. In this way, bias due to eye fatigue was avoided and a reasonable degree of homogeneity of stain intensity in each group was achieved.

RESULTS

Since the width of the zona fasciculata varies with size of the adrenal gland as well as the size of the microscopic section of the gland which is examined, a ratio of the width of the zona fasciculata to the width of the total zona fasciculata-zona glomerulosa region was used for comparative purposes. Hypertrophy of the cortex is due mainly to enlargement of the zona fasciculata (Greep and Deane, 1949), although the innermost zona reticularis may also increase in width (Flexner and Grollman, 1939). The outer zona glomerulosa generally fails to take an important part in these changes. In most cases it is not difficult to distinguish these three zones in the adrenal cortex of the cotton rat, but it is difficult to decide where the zona reticularis ends in the adrenal medulla. For this reason the width of the entire cortex was not used as a criterion of adrenal activity. The ratio of the zona fasciculata to the zona fasciculata plus zona glomerulosa for live-trapped and non-live-trapped rats captured in 1959 is shown in Table 1. The t-test (t=3.28, 74 degrees of freedom) showed that the ratio for live-trapped rats was significantly greater than that for non-live-trapped rats, indicating that the zona fasciculata had increased in width in previously handled animals.

The results of the examination of adrenal tissue stained with Sudan III (Table 2) indicated a tendency toward greater quantities of lipid in the cortex of live-trapped rats. The chi-square test of homogeneity (X^2=5.032, 1 d.f.) was significant at about the .03 percent level, indicating that the live-trapped and non-live-trapped rats were from statistically different populations. Although there is considerable variation in the staining reaction, the trend is toward darker stain for live-trapped rats and toward lighter stain for non-live-trapped rats.

Weight changes of fresh adrenal glands supported the histological findings. Because adrenal gland size is linearly proportional to body weight, and may be influenced by sex and age, the adrenal gland weight data were subjected to an analysis of covariance. When the data were separated by sex, age, and year captured, the mean adrenal gland weight of live-trapped rats was consistently greater than that of non-live-trapped rats (Table 3) in every group except the adult males in 1958. However, the analysis of covariance showed that these differences were not significant at the 95 percent level. Apparently the small amount of moisture and fat unavoidably associated with the tissue introduced considerable variation into the adrenal weight data. Since the adrenal glands were used for histological study, it was not possible to determine the dry weight which might have provided a more reliable criterion of adrenal size and activity. Nevertheless, the consis-

TABLE 2.—STAIN REACTION OF SUDAN III IN ADRENAL GLANDS OF COTTON RATS RELATED TO THEIR CAPTURE IN LIVE TRAPS

Group	Very Dark	Dark	Medium	Light	Very Light	Total
Live-trapped						
Number	6	6	8	2	5	27
Percent of total	22	22	30	7	19	100
Non-live-trapped						
Number	6	13	8	11	11	49
Percent of total	12	27	16	23	22	100

TABLE 3.—MEAN WEIGHT (GRAMS) OF FRESH ADRENAL GLANDS OF COTTON RATS RELATED TO NUMBER OF CAPTURES

Year	Sex	Age	Not Live-trapped		Live-trapped						Total Live-trapped	
					Once		Twice		Three or More			
			No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
1958	–	Juv.	37	.0152	4	.0254	2	.0173	12	.0143	18	.0162
1958	M	Ad.	4	.0349	1	.0326	–		–		1	.0326
1958	F	Ad.	6	.0514	3	.0741	4	.0573	1	.0740	8	.0657
1959	–	Juv.	31	.0152	12	.0162	3	.0269	2	.0112	17	.0175
1959	M	Ad.	10	.0213	2	.0306	1	.0277	–		3	.0296
1959	F	Ad.	13	.0434	4	.0425	4	.0527	1	.0421	9	.0470
Average			101	.0224	26	.0297	14	.0417	16	.0194	57	.0291

tent trend of greater adrenal gland weight for live-trapped rats does point to the same conclusion indicated by the histological findings.

We might expect that adrenal gland weight would be related to frequency of capture in live traps. A tendency for the weight change to become more apparent with each trapping of the animal was found when all the data were considered together (see Table 3), especially when rats trapped once were compared with those captured twice. Unfortunately, the small numbers and preponderance of juveniles captured three or more times makes further comparisons unreliable.

DISCUSSION

The investigator studying adrenal gland activity in a natural population often faces more variation in experimental material than would be encountered in a laboratory population. In this study the live-trapped category included rats trapped one to seven times, with the dates on which different animals were trapped varying with respect to the 8 days. During the study no animals were live-trapped on the 8th day only and snap-trapped on the 9th day. In every case at least 3 days had elapsed between the first time of capture and the date of snap-trapping, and in 87 percent of the rats, at least 5 days elapsed between initial and final capture. Even with this variation in frequency and time of capture, a clear trend toward increased adrenal gland activity associated with live-trapping is evident.

The increase in adrenal activity suggests that the live-trapped cotton rats were subjected to stressful conditions—to "trap stress." The histological condition of the adrenal glands, as seen in the width of the zona fasciculata and the quantity of lipid, indicated that the live-trapped rats were in the resistance or adaptation phase of Selye's stress syndrome (Selye, 1950) and that the rats adapted to trap stress in about 5 days. Since Selye has shown in the laboratory that increasing or continued stress may result in a decline in reproductive activity and eventually in death, we might speculate that the imposition of trap stress on an already stressed adrenopituitary system may influence reproductive activity and survival and produce changes in population density. At least, an investigator studying the ecology of mammals by intensive live-trapping should consider the possibility that repeated handling may induce changes in the natality and mortality of the sample from which he draws conclusions about the entire population.

SUMMARY

The hypothesis that repeated handling of small mammals in live traps may induce changes in adrenal cortex activity was tested in a population of cotton rats living in their natural habitat. Change in the width of the zona fasciculata, in quantity of lipid in the cortex, and in adrenal weight were used as criteria of adrenal gland activity. All three criteria indicated increased adrenal gland activity in animals previously handled as compared with those newly handled.

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MOURNING DOVE FOODS IN TEXAS DURING SEPTEMBER AND OCTOBER

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The study reported here was conducted in Texas to gather information on the September and October feeding habits of mourning doves (*Zenaidura macroura*) and the importance of agricultural crops and weeds as food items. Limited data on Texas dove foods during these months were reported by Jackson (1941).

Murry (1952) found that plants of the grass, spurge, spiderwort, and composite families, made up 93 percent of the food of Louisiana mourning doves on agricultural lands.

Rosene (1939) said that preferred feeding places were on bare ground in open situations and that an abundant food supply concentrates doves. This requirement limits feeding areas to crop fields and open pastures or woodlands having seed on top of the ground rather than buried in deep duff or litter.

Jackson (1941) stated that combine harvesting and rapid shallow plowing (a weed and wind erosion control measure) favor dove foods. Fields may be plowed by this method several times in a season, a practice that benefits doves by exposing new seeds at each plowing.

Data gathered in Beckwith's (1959) investigation agree with the findings of workers elsewhere, which show the mourning dove to be almost exclusively vegetarian. My study shows only trace amounts of animal foods.

Despite the general similarity in dove food hab-

[1] Assistance in identifying seeds was given by A. C. Martin and Neil Hotchkiss, U.S.D.I., Bureau of Sport Fisheries and Wildlife. L. V. Compton, P. F. Allan, V. E. Davison, and A. E. Borell of the Soil Conservation Service, and O. H. Hewitt of Cornell University assisted with their critical reviews of the manuscript.

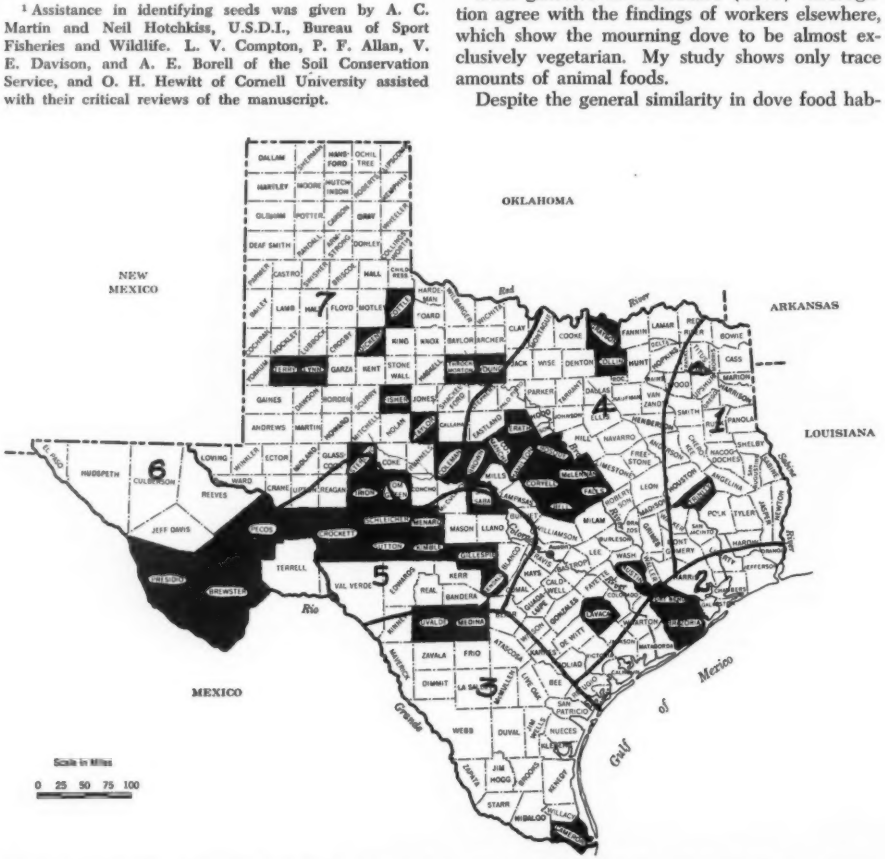

FIG. 1. Counties where dove crops were obtained, shown in relation to the plant zones of Texas (Cory and Parks, 1937).

its reported by various workers, there are specific local and seasonal differences. The present study covers only a short period. Additional studies throughout the year are needed to complete our knowledge of mourning dove food habits in an area as large as Texas.

Texas is divided into northern and southern zones for mourning dove shooting. The dividing line runs roughly from Del Rio on the Rio Grande eastward to San Antonio, thence diagonally northeastward across East Texas following county lines. The northern zone opens to hunting on September 1 and the southern zone on October 1. The length of the season is about 6 weeks.

Six hundred and fifty-one mourning dove crops were analyzed in this field study. They were collected by the author, his colleagues in the Soil Conservation Service, and by farmer or sportsman friends during the hunting seasons of 1957, 1958, and 1959. The collections came from the 43 Texas counties (Fig. 1).

Mourning doves usually have ample seeds in their crops for an adequate sample since they are killed in or near agricultural fields while feeding or around farm ponds at which they drink before going to roost shortly after feeding. Davison (1940) emphasized the use of crop analyses in food habit studies because the crop is the only portion of the alimentary canal from which food may be retrieved in the same proportion in which it was eaten. The field method of crop analysis, as described by Davison, was used in this study.

The volume percent method described by Martin, *et al.* (1946) was used to record the data. Quantities as small as 0.1 cc. were measured in the individual crop. Anything less than 0.1 cc. was recorded as a "trace." In the final tabulation, any food item of 0.1 percent or less was considered a trace amount.

RESULTS

Data were derived from analyses of 651 mourning dove crops collected in 43 Texas counties well distributed throughout the State (Fig. 1). Results are shown in Table 1. Variation in the food items was insufficient to justify separation of the data by land resource areas.

Food items.—The period of September and October, covered by this study, is ordinarily a period of abundance. Doves proved to be so selective of foods that four plant families—grass, spurge, com-

TABLE 1.—PRINCIPAL FOODS OF 651 MOURNING DOVES IN TEXAS DURING SEPTEMBER AND OCTOBER (1957–59)

FOOD ITEMS[1]	Percent by Volume	Percent by Occurrence	Plant Zones[2]
PLANT FOOD			
Grain sorghum (*Sorghum vulgare*)	19.4	33	all
Oneseed croton (*Croton monanthogynus*)	18.8	46	1, 2, 3, 5, 7
Annual sunflower (*Helianthus* spp.)	14.8	37	all
Browntop panicum (*Panicum fasciculatum*)	6.5	23	all
Woolly croton (*Croton capitatus*)	5.4	10	2, 3, 4, 5
Prostrate amaranth (*Amaranthus blitoides*)	4.1	26	3, 4, 5, 6, 7
Texas croton (*Croton texensis*)	4.0	17	3, 4, 5, 6, 7
Johnson grass (*Sorghum halepense*)	3.6	23	all
Stillingia (*Stillingia* spp.)	3.3	6	1, 2, 3, 4, 5, 7
Wheat (*Triticum aestivum*)	2.9	7	1, 4, 5, 6, 7
Oats (*Avena sativa*)	2.1	5	1, 2, 3, 4, 5, 7
Spurge (*Euphorbia* spp.)	1.6	6	all
Rye (*Secale cereale*)	1.5	2	5, 6, 7
Threeseed croton (*Croton lindheimerianus*)	1.4	5	2, 3
Noseburn (*Tragia* spp.)	1.3	6	2, 3, 4, 5, 6, 7
Prickly ash (*Xanthoxylum* sp.)	1.2	3	all
Amaranth (*Amaranthus* spp.)	0.9	13	all
Tropic croton (*Croton glandulosus*)	0.9	3	1, 3, 4, 5, 7
Verbena (*Verbena* spp.)	0.8	15	all
Pricklepoppy (*Argemone* spp.)	0.8	6	all
Caltrop (*Kallstroemia* spp.)	0.8	9	2, 3, 4, 5, 7
Corn (*Zea mays*)	0.7	6	all
Texas panicum (*Panicum texanum*)	0.5	2	2, 3, 4, 5, 7
Witchgrass (*Panicum capillare*)	0.4	6	1, 2, 4, 7
Signal grass (*Brachiaria* spp.)	0.4	1	1, 2, 3, 4, 5
Euphorbia (*Euphorbia marginata* or *E. bicolor*)	0.4	2	1, 2, 3, 4, 5, 6, 7
Birdseye (*Caperonia castaneaefolia*)	0.3	1	2
Paspalum (*Paspalum ciliatifolium* or *P. langi*)	0.2	3	1, 2, 3, 4, 5
Total plant food	99.9		
ANIMAL FOOD	Trace		

[1] Names from Kelsey and Dayton (1942).
[2] From Cory and Parks (1937).

posite, and amaranth — made up 95.4 percent of the foods found in this study, despite the abundance of many other possible foods. Four other families—rue, verbena, poppy, and caltrop—provided 3.6 percent of the food used. Seeds of 35 other plants and 3 animal foods were identified in small amounts but together made up less than 1 percent of the food used. Seeds in very small volume or found as trace items in 8 or fewer of the 651 crops were disregarded.

Corn, a dove food of high preference in other regions, did not figure importantly in this study. This reflects a change in Texas agriculture. Grain sorghum is rapidly replacing corn in Texas as a cash crop.

Animal food consisted of snail shells, grasshopper eggs, and small beetles in trace amounts. The small beetles were found twice in crops containing prostrate amaranth seeds. They were about the same size and color as the amaranth seeds and probably were picked up accidentally.

Rodent damage (tooth marks and cleanly removed seed germs) to the grain sorghum seeds appeared in the sample in all 3 years. Insect damage was common in annual sunflower seeds as evidenced by holes in the seed coat and larvae in the seed. Rapid deterioration and germination make grain sorghum and annual sunflowers undependable as a yearlong food. Damaged seeds deteriorate rapidly and undamaged ones germinate with the first moisture that falls in the long, warm, moist fall common in most of Texas. In contrast, many of the wild or weedy types of seeds are durable and slow to germinate. One could separate from the crop contents the newly produced seeds and the older ones that had weathered. Seeds of oneseed croton, browntop panicum, queen's delight, and caltrop, especially, could be so separated. Old weathered seeds of grain sorghum, wheat, oats, and annual sunflower were rarely found in crops.

DISCUSSION

The important seeds used by mourning doves indicate that they feed primarily in or near agricultural crop fields in Texas, as elsewhere. When agricultural crop residues are available, they furnish important dove foods. When they are not available, the hard seeds of spurges and grasses are highly important. Five of the most important foods were agricultural crops; 12 were weeds of cropland; 7 were weeds that grow both in cropland and pastures or rangeland; 2 were typical of pasture and rangeland; and 2 grow in field borders or hedgerows. Seeds of these 28 plants represent 99 percent of the food of the 651 mourning doves in this study(Table 1). All but two, paspalums and prickly ash, were annual plants. Prickly ash was the only woody plant that produced seeds used in a significant amount.

The extensive acreages of grain sorghum, wheat, oats, and rye in Texas assure mourning doves of an abundance of food after crops are harvested. The use of mechanical harvesting devices provides an abundance of shattered grain on the ground from spring (wheat, oats, and rye) to fall (grain sorghum and corn).

Even with modern cultural practices, weeds grow in profusion in fields and especially in field borders and fencerows. Following the spring harvest of wheat, oats, or rye, an excellent volunteer crop of croton and browntop panicum grows in the stubble. Stubble is not plowed under or destroyed, as was formerly done; consequently the field will have protective cover to prevent wind erosion.

Tillage of fields brings to the surface seeds of crotons, panicums, queen's delight, and others. These same seeds may be exposed by rain.

Not all agricultural practices favorable to doves can be considered good farming methods. Pasture and range weeds such as crotons, queen's delight, and others become abundant when pastures or ranges are heavily grazed or subjected to prolonged drought.

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OUTER PRIMARIES AS INDICATORS OF AGE AMONG ROCK PTARMIGAN[1]

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In his extensive review of characteristics useful for determining age in upland game birds, Petrides (1942. Age determination in American gallinaceous game birds. Trans. N. Amer. Wildl. Conf., 7:308–328.) suggested that the shape and color of the outer primaries indicated age in ptarmigan as in other Tetraonidae. Among the 38 willow ptarmigan he examined, the shape of the outer primaries (whether pointed or rounded) was not at all reliable, but color (whether mottled or clear) was better. When both criteria were used together, 1 juvenile and 28 post-juvenile rock ptarmigan seemed to have the appropriate signs of age; 2 specimens were doubtful. Of the 19 juvenile white-tailed ptarmigan, 2 had clear outer primaries (supposedly an adult characteristic) but all had pointed ones. Only 1 doubtful specimen was found among 25 post-juvenile birds examined.

In view of the persistent occurrence of "doubtful" specimens in the birds examined by Petrides, and because of the small samples he was able to study, it was decided to test the usefulness of the color and shape of outer primaries for age determinations on rock ptarmigan during a study begun in 1959 by the Alaska Department of Fish and Game. If the method were accurate, it would have many advantages over other known ways of determining age. The locating of the bursa of Fabricius, present in young of gallinaceous and other birds, requires the examination of live birds or whole carcasses. The post-juvenile molt of rock ptarmigan is complete in mid- or late September, and by mid-October all primaries of young and old alike are fully grown and have lost their sheath. Other supplementary characters, such as the softness of the cranium, the strength of the lower mandible and the presence of scars on the claws, lose their value at an undetermined time in the fall. I did not examine the tips of the primaries to see if young and old could be distinguished by the amount of wear on the outer remiges, as suggested by Ammann (1944. Determining age of pinnated and sharptailed grouses. J. Wildl. Mgmt., 8:170–171.). Frequently there is only a 2- or 3-week difference in the age of the outer primaries between adult ptarmigan and young-of-the-year, rather than a month or more as in prairie grouse; as a result, there probably is not much difference in wear in ptarmigan.

A sample of 164 young and 33 adult rock ptarmigan collected in late August, September, and early October of 1959, and an additional 86 young and 6 adults shot in 1960 in central Alaska, were used in the test. The age of the birds was determined as follows:

1. The two outer remiges of rock ptarmigan come in when the chick is in its fifth week. These feathers are kept for a full year. The brown juvenile primaries (numbers 1–8) begin to drop when the chick is 3 weeks old. At that time the innermost primary is replaced by a white one. In August and September, therefore, young ptarmigan have juvenile (brown) or newly grown, short, white primaries in the middle of the series. Some juveniles in the fall have one or more brown secondaries, instead of the white ones possessed throughout life after the post-juvenile molt is complete. Adults collected in September and early October have primaries 9 and 10 either worn, old, and frayed or newly molted; the other eight are full-length.

2. Young females are distinguishable from hens that have ovulated, as the follicles of the young birds are small and uniform in size and color, giving the ovary a smooth appearance. The ovaries of adults are pebbly, as the follicles are of varying size and color. The oviduct of adults is opaque and larger than that of the young. These characters persist well into the winter.

In every specimen the bursa of Fabricius was checked except when it was shot away or pulled out when the bird was eviscerated. The bursa was present and between ¼ and ½ in. long in each of 152 birds with the juvenile characters listed above (measurements taken of the bursa in the body cavity, not from the external opening of the cloaca). None of the 27 birds examined with adult characters had bursae. The time of disappearance of the bursa is not known. Of 11 rock ptarmigan with mottled 9th primaries collected in November and December, 10 had bursae between ⅛ and ¼ in. long, and one had only a tiny bump where the bursa should have been. Nine males were collected in March and April 1960; three had bursal remnants too small to measure and six had no bursa. From the absence of bursae in fall-shot adults and the presence of small bursae in birds shot in November and December, it appears that some juveniles must lose their bursae in midwinter.

Shape of Outer Primaries

Among Tetraonidae, the first set of outer primaries usually is more pointed than subsequent sets. To arrive at some objective means of deciding on relative shape of primaries, I took the following measurements on each of the outer two remiges: (1) the width of the feather 2 mm. from the tip, measured as a perpendicular across the shaft; (2) the length of the barb that originates

[1] A contribution from Pittman-Robertson Research Project W-6-R-1 (I-2), Game Division, Alaska Department of Fish and Game.

TABLE 1.—MEASUREMENTS OF THE OUTER PRIMARIES OF ROCK PTARMIGAN

Measurement	No. of Birds		Range (mm.)		Mean (mm.)		Variance (S^2)	
	Adult	Young	Adult	Young	Adult	Young	Adult	Young
Width 2 mm. from tip								
P9	31	144	3.2 – 5.6	2.4 – 4.7	4.4	3.6	0.5	0.4
P10	27	150	3.0 – 5.0	2.2 – 4.3	4.1	3.4	0.5	0.4
Length of barb originating 5 mm. from tip								
P9	31	149	4.0 – 5.3	3.6 – 5.6	4.6	4.5	0.1	0.4
P10	26	150	3.4 – 5.0	3.2 – 4.6	4.4	4.0	0.3	0.1
Sum of above measurements, both primaries	25	142	13.9 –20.3	12.8 –17.6	17.5	15.5	1.3	1.0
Width 20 mm. from tip								
P9	29	145	10.0 –12.6	9.3 –12.8	11.4	11.2	0.7	0.8
P10	24	150	7.2 –10.3	7.1 –11.4	8.9	8.8	0.7	0.7
Ratio: Width at 2 mm. / Width at 20 mm.								
P9	29	142	0.27– 0.48	0.24– 0.43	0.39	0.33	0.05	0.04
P10	24	149	0.33– 0.57	0.25– 0.50	0.46	0.39	0.05	0.05

5 mm. from the tip on the wider (inner) side of the feather; (3) the width of the feather 20 mm. from the tip. Two additional measures of roundness were compared between young and old: the sum of the first two measurements of both primaries, as listed above, and the ratio of the width at 2 mm. to the width at 20 mm. The measurements (Table 1) were taken with vernier calipers to tenths of millimeters. Only birds collected in 1959 were used in the test.

None of the measurements taken showed a statistically significant difference between means for young and old. The method would be unreliable even if such differences in means did exist, because so many individual measurements overlapped those of the other age class. Even after the analysis just described, however, I am not satisfied that the usefulness of shape must be discounted totally. When the wings are examined "subjectively," there does appear to be a difference in most (but certainly not all) cases. In such a study, the eye is assessing shape by summing up many measurements. In the attempt at objectivity just described, only three actual measurements were taken to determine shape. Nevertheless, it seems clear that there always will be a number of birds that have the "wrong" characteristics of primary shape, making the method unreliable for studies requiring considerable accuracy in age ratios determined from samples.

COLOR OF OUTER PRIMARIES

The entire sample of 197 rock ptarmigan collected in 1959 was examined to find out whether the presence of mottling on the outer primaries was indicative of age. The 8th, 9th, and 10th primaries were examined; the 9th (P9) turned out to be the most important. Best results were obtained when any feather with brownish mottling or speckles was listed as "dark," even though the amount of mottling was very small. Since the shafts of the primaries (except P10) were brown

TABLE 2.—COLOR CHARACTERISTICS OF PRIMARIES 8, 9, AND 10 OF YOUNG AND ADULT ROCK PTARMIGAN

Color Characteristics	Young[1]		Adults[1]	
	Number Positive	Percent Positive	Number Positive	Percent Positive
P8, P9, P10 with dark areas	2	1	4	12
P9, P10 dark, P8 light[2]	17	10	0	
P10, P8 dark, P9 light	0		0	
P9, P8 dark, P10 light	13	8	6	18
P8 dark (not considering P9, P10)	15	9	16	48
P9 dark (not considering P8, P10)	158	96	11	33
P10 dark (not considering P8, P9)	19	12	4	12
P8 dark, P9, P10 light	0		6	18
P9 dark, P8, P10 light	126	77	1	3
P10 dark, P8, P9 light	0		0	
P8, P9, P10 light	6	4	16	48

[1] 164 young and 33 adults examined.

[2] Primaries which were speckled or marked in any way with dark color on the vane (shafts not considered) were termed "dark." Feathers without such markings were called "light."

or black in all specimens, whether young or old, only brown coloration of the vane was recorded. The results of the study are given in Table 2. After all combinations had been tested, the most useful consideration seemed to be that of P9 alone. The sample of 92 rock ptarmigan obtained in 1960 was tested for the presence or absence of dark areas on P9 only; 83 out of 86 young birds (96 percent) had dark areas, whereas 2 of 6 adults also had dark areas. Of the combined sample of 250 young from both years, 96 percent had mottled ninth primaries; of 39 adults, 33 percent also had brown coloration on P9.

Considering all cases where sex was known (13 adult males, 26 adult females, 74 young males, and 97 young females), I found that about 46 percent of the adult hens had dark areas on P9, but only 1 (8 percent) of the adult cocks did. Among young birds, 93 percent of the males and 99 percent of females had this coloration. The bias injected into samples of unknown-age birds is clear: more of the young males will be mistaken for adults than will young females, whereas almost half of the older hens will be classed as young-of-the-year.

There are some indications from studies of broods of rock ptarmigan in 1960 that the genetic determinants of dark areas on the primaries (as to both amount and shape, since it is evident that there are a limited number of patterns of coloration) are inherited in a fairly simple manner. One or two broods were found in which all of the chicks that could be captured had a certain pattern of color on the primaries, and a few other broods had chicks with either large amounts of dark color, or very little. One brood of six chicks, of which three were caught, contained at least two that had "adult" primary characteristics, and one other that had only a tiny amount of dark on the vane of P9. Much more information will be needed before anything conclusive can be said about this color phenomenon.

SUMMARY

Shape and pigmentation of the outer primaries of rock ptarmigan proved to be unsatisfactory as age criteria in a sample of 250 young and 39 adults collected in interior Alaska in autumn. Subjectively, tip shape showed too many intermediate individuals; when reduced to a series of measurements, the means were not significantly different and there was much overlap. Whereas 96 percent of the young-of-the-year showed pigmentation of the vane of the 9th primary, so did 33 percent of the adults. Fewer males than females had pigmentation on the 9th primary, and those that did have pigmentation frequently had less than most females.

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GRIT SELECTIVITY BY THE FEMALE PHEASANT DURING EGG PRODUCTION

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The purpose of this study was to determine (1) if selectivity for limestone grit occurred in penned female pheasants (during the egg-laying season); and (2) if changes in the amount of grit consumed fluctuated when the hens were fed different levels of calcium in the base ration.

Several investigators have suggested that distribution of pheasants in North America might be limited by availability of calcium-bearing grit (Leopold, 1931; Gerstell, 1937; McCann, 1939; and Dale, 1954). Their premise is based on the fact that pheasants are largely gramnivorous and cereal grains are almost devoid of calcium (Morrison, 1948). The role of this essential mineral becomes increasingly important during egg laying.

If pheasants have the capacity to select calcareous grit in response to a calcium deficiency, even limited supplies of limestone might satisfy their calcium requirements. McCann (1939) reported selectivity by pheasants for glacial gravel over limestone and quartz, but gave no explanation for high utilization of glacial gravel. Presumably, both glacial gravel and limestone contained calcium. No mention was made of the calcium content of the ration, which could have a bearing on the nature of grit requirements of pheasants. Dalke (1938) examined pheasant gizzards from southern Michigan and found few calcareous grits. He reasoned that the highly erodible nature of this material accounted for its absence in the gizzard.

The author wishes to extend thanks to Thomas S. Baskett, Leroy J. Korschgen, Bill T. Crawford, and Howard M. Wight for critically reading the manuscript and offering advice on presentation of the data. Thanks are also due the Iowa Conservation Commission for supplying experimental birds.

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MATERIALS AND METHODS

On March 18, 1960, 6 male and 42 female pheasants were placed in six 10- × 24-ft. breeding pens. The males were blackneck pheasants wild-trapped in Iran, the females were Iowa ringnecks, two generations removed from the wild. All 48 birds were fed a commercial game bird laying ration (Ralston Purina Layena) which contained acceptable levels of protein (20 percent),

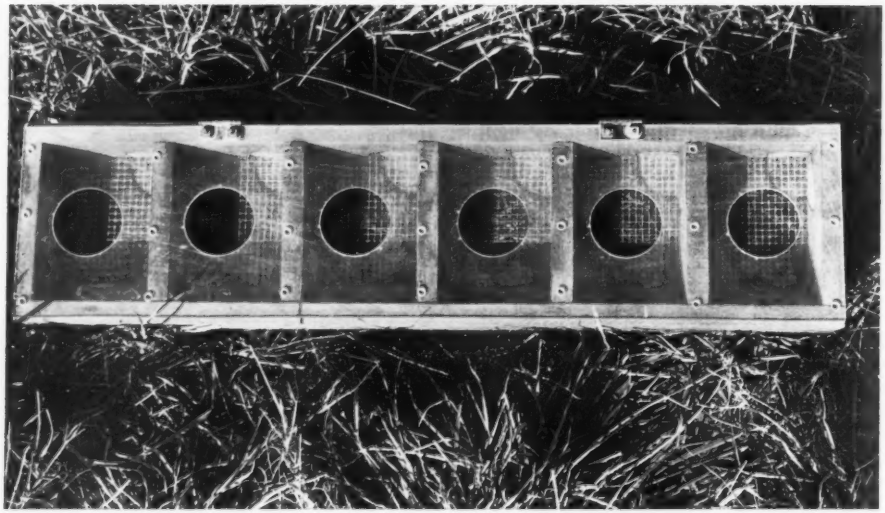

FIG. 1. Grit feeder. Dimensions are 30 × 7½ × 2¾ in. The holes in the Plexiglas lid have 2½-in. diameters.

NFE (47 percent), vitamins and minerals. Total calcium, by independent analysis, was about 2.65 percent. The ration was fed *ad lib*. Beginning April 1, spill-proof grit containers, divided into six compartments, were put into each pen (Fig. 1). The end compartments were left empty to eliminate an accessibility bias. The interior four compartments contained alternate supplies of "wheat size" granite and limestone grit. The grit materials were washed and screened to a uniform size. At 2- to 3-week intervals grit consumption was recorded to the nearest ¼ oz. The supply was then replenished. Beginning May 12 the calcium content of the ration was reduced to 0.53 percent total calcium and remained at this level throughout the remainder of the study. Beginning June 7 only one of the four compartments in each pen was filled with limestone; the remainder contained granite.

RESULTS

The reduction in calcium content of the ration from 2.65 percent to .53 percent was made during the period of maximum egg production (Table 1). This sharp reduction had no effect on egg production but did elicit a dramatic change in grit utilization. During the period April 25 to May 11 the birds ate a combined total of 1.3 oz. of grit daily. Following calcium reduction the combined total grit consumption for the next 13 days averaged 5.4 oz. per day, an increase of over 400 percent. Egg production before and after the ration change

TABLE 1.—LIMESTONE AND GRANITE GRIT CONSUMPTION OF 42 FEMALE AND 6 MALE PHEASANTS FED RATIONS CONTAINING DIFFERENT LEVELS OF CALCIUM, APRIL TO SEPTEMBER 1960

Dates	Total Grit Consumed (ounces)	Grit Consumption Per Day (ounces)	*Granite* (percent of total)	*Limestone* (percent of total)	Total Egg Production Per Day
Apr. 1–Apr. 24	37.0	1.5	40.5	59.5	6.8[1]
Apr. 25–May 11	22.5	1.3	26.7	73.3	26.3[1]
May 12–May 24	64.7	5.4	19.7	80.3	30.2[2]
May 25–June 6	44.0	3.4	0.0	100.0	29.5[2]
June 7–June 20	48.7	3.5	2.6	97.4	28.6[3]
June 21–July 11	39.0	1.8	4.7	95.3	17.8[3]
July 12–Sept. 7	28.0	0.5	36.6	63.3	2.3[3]

[1] Commercial game bird laying ration with 2.65 percent total calcium.
[2] Commercial game bird laying ration with 0.53 percent total calcium.
[3] Commercial game bird laying ration with 0.53 percent total calcium with granite: limestone grit availability ratio changed from 2:2 to 3:1.

remained about the same, 26.3 eggs per day before, and 30.2 afterwards. The percentage of limestone taken increased abruptly following reduction of calcium in the ration. Limestone accounted for 80.3 percent of the grit taken during the first 13 days. During the next 25 days (May 25 to June 20) only a token amount of granite (1.3 oz.) was eaten. In this same period 91.4 oz. of limestone were consumed.

Changing the ratio of feeder compartments containing limestone and granite from 2:2 to 1:3 later in the study did not alter the selection of limestone. The birds simply consumed as much from one compartment as they had previously from two. Conversely, the increase in availability of granite grit did not increase its utilization. The seasonal reduction in egg laying was accompanied by a more nearly equal utilization of granite and limestone grits.

These results all strongly suggest that the hen pheasant has the capacity to select calcium-bearing grit, if it is available, to compensate for any lack of this essential element in the diet. There can be little doubt that pheasants are very sensitive to the level of calcium in their diet and react promptly to a reduction of this element.

While the study was weakened somewhat by the inclusion of the male birds, it seems improbable that they altered the results substantially. Dalke (1938) found that male pheasants during the breeding season individually consume less grit than females. Studies in Missouri (Korschgen, 1959) during April and May show the weight of female gizzard stones averaged 4.42 grams per bird compared with 3.29 for males. It was further found that female gizzards contained about five times more calcareous gravel than male gizzards. Lastly, 87.5 percent of the experimental birds were females. All of Korschgen's evidence tends to minimize the effect of the inclusion of male birds in the study.

DISCUSSION

One of the implications of this study is that if the wild hen pheasant's diet is calcium deficient, she can select calcareous grit if it is available. Areas in Missouri which seemingly have small amounts of calcareous grit are often underlain with limestone. These subsurface deposits have provided an economical source of secondary road surfacing material, especially in the northern half of the state. This quarried limestone is an excellent potential source of calcium for pheasants. Despite the fact that limestone may account for only a small percentage of the total grit available, calcium needs might be met by grit selectivity. Application of agricultural limestone, a common practice in this area, would also contribute to the amount of calcareous grit available. These sources of calcium do not preclude the possibility that pheasant distribution is limited by calcium availability south of the "pheasant line." It does suggest that calcium-bearing grit need not be abundantly available, as might be the case if grits of different types were taken randomly.

Funk (1932) and others have shown that domestic chickens have the ability to select a reasonably well-balanced ration from individual ingredients. It would seem that pheasants share this capacity, at least as far as calcium is concerned.

SUMMARY

Female pheasants showed a capacity for selection of calcium-bearing grit (limestone) over non-calcareous grit (granite) during egg laying. This selection was clearly indicated when the birds were fed a low (0.53 percent) calcium diet. Lowering the calcium content of the ration from 2.65 to 0.53 percent resulted in a substantial increase in total grit consumption, nearly all of which was calcareous. Raising the ratio of availability of granite over limestone had little effect on the selection of the limestone.

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ATLANTIC WHITE-CEDAR AS A WINTER DEER BROWSE

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Atlantic white-cedar (*Chamaecyparis thyoides* (L.) B.S.P.) grows in a narrow coastal belt from southern Maine to northern Florida and westward through southern Mississippi (Harlow and Harrar, 1941). It occurs very commonly in pure stands on low wet ground, usually on sandy soils or peat deposits with underlying sandy soils (Little, 1959).

Atlantic white-cedar has seldom been mentioned as a nutritional deer browse while northern white-cedar (*Thuja occidentalis* L.) is recognized as a superior winter browse for deer. Because this difference exists in the literature, we made nutritional comparison of the two species. The results may stimulate interest in Atlantic white-cedar as a winter browse for deer and may encourage future studies of its use by deer.

Ten samples of Atlantic white-cedar were collected during the winter from 10 widely separated areas in Rhode Island. These were analyzed by R. W. Gilbert, University of Rhode Island Agricultural Experiment Station at Kingston.

Five samples of northern white-cedar were collected in the Cusino Swamp area near Shingleton, Michigan by L. A. Davenport during the winters of 1937–39. These were analyzed at Michigan State University in the Agricultural Experiment Station Laboratory. The data on these were supplied by D. F. Switzenberg and L. J. Verme of the Michigan Department of Conservation.

The data from the two tests (Table 1) suggest that Atlantic white-cedar may be a winter browse comparable with northern white-cedar. Moreover, the dense growth of the former in these lowland sites provides excellent winter cover. Investigations in the New Jersey Pine Region (Little, *et al.*, 1958) revealed that Atlantic white-cedar provided the bulk of the winter food of deer on lowland sites. Limited field observations in Rhode Island support these findings. Therefore, it would seem that the value of the Atlantic white-cedar as food and cover for deer should be more fully evaluated.

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Table 1. Mean Proximate Analysis of Atlantic White-Cedar and Northern White-Cedar Browse
(All figures are expressed as percent calculated on a green weight basis)

Species	Moisture	Crude Protein	Ether Extract	Crude Fiber	Ash	Nitrogen-Free Extract	Calcium	Phosphorus
Atlantic White-Cedar[1]	54.3	3.4	3.5	13.1	1.3	24.4	0.38	0.06
Northern White-Cedar[2]	55.8	3.2	5.6	11.6	1.9	21.8	0.57	0.05

[1] Based on 10 samples. Standard errors of the mean are respectively: 0.39, 0.09, 0.09, 0.12, 0.08, 0.33, 0.013, and 0.003.

[2] Based on five samples. Variance data not available.

BOOK REVIEWS

Oysters. By C. M. Yonge. Collins, London. 1960. xiv + 209pp. 21 shillings (about $3.00).

This book is one of the New Naturalist series, of which the stated aim "is to interest the general reader in the wild life of Britain by recapturing the inquiring spirit of the old naturalists." Just how successful it will be with the general British public I would not presume to guess; but it certainly captured my interest and I found, a little to my surprise, that I could not dash through it hurriedly.

North America probably produces as many oysters as the remainder of the world. It is somewhat peculiar, therefore, that the last general American work on oysters is that of W. K. Brooks (1905), whereas three have come from French and British sources in the past 25 years, all from eminent authorities who in different ways have increased our knowledge of oysters. Brooks' *The Oyster* is now out-of-date biologically, but remains of historical value.

I tell career students in marine biology that they should undertake to learn something about oysters because, if they remain in the field, the chances are high that someday they will be confronted with oyster problems. If this advice is

followed the student should begin with Gilbert Ranson's *Les Huitres, Biologie-Culture* (Lechevalier, Paris, 1951), which is a revision of an earlier work. This is a semipopular account, which holds rather evenly to that aim and is easy reading. It is, of course, in French.

Frank Buckland was an outstanding British student of oyster culture of almost 100 years ago. His memory is commemorated annually by the Buckland Lectures upon subjects related to marine fisheries. These are always published, and are of notable clarity. J. H. Orton's lectures in 1935 were published as his book, *Oyster Biology and Oyster-Culture* (1937). This is an excellent text for the general public because it starts off with simple propositions and proceeds to more complicated matters. It also differs from the other two works under discussion because it presents much of the data upon which the conclusions are based. This book should be read second in the trilogy. It sticks fairly close to the British situation and a great deal of work has been done since it was published so that it is a little out-of-date.

Professor Yonge's work is quite different from the other two. He has contributed extensively to oyster biology, but he has not confined himself to oysters alone and has a broad knowledge of Mollusca in general. The advantage of this broader viewpoint is plainly seen, for throughout the text he makes comparisons of the oyster to other mollusks in a way which is generally lacking in the other texts. This is particularly true in the first chapter, in which the writer discusses the origin and status of oysters. This is followed by chapters on description of the oyster; reproduction and development; species and distribution; life and habits; enemies, competitors, and diseases; oysters in the past, and, finally, oyster culture.

The book is short. The author indicates in the preface that he was pressed for time and virtually wrote the book between planes. There is some indication of this method, for not all topics are evenly covered. However, in general, they are concisely, and some even brilliantly, dealt with in a way that leads the reader up to the frontier of knowledge about oysters. The beginning student can do no better than to read this book; parts of it may be heavy going for the general reader.

Yonge has evidently discussed extensively only those subjects of his own choosing, while other subjects are given lighter treatment. The citations are somewhat spotty, even though it is apparent from the text that the author is cognizant of the uncited works. For instance, no references of Japanese workers are given, and some people who have contributed considerably to American studies on the oyster are omitted, whereas others who have contributed much less, in my opinion, are mentioned several times. Ranson's book is not cited. Nevertheless, the references in this book will guide the serious student to the literature on oysters.

The book is well illustrated and remarkably free from typographical errors. I noted five. There are few statements with which anyone would disagree. In his preface the author states that oyster culture is as intense and highly organized as any method of agriculture. That may be true, but without further detail it leaves the wrong impression. In the Pacific Northwest, in France, and in parts of Japan the statement applies, but in a great many parts of this country oyster culture is still a crude industry. Furthermore, because of intrinsic difficulties, oyster culture certainly does not have the stability of agriculture.

Pycnodonta is used for one of the three living genera of Ostreidae, but it should be *Pycnodonte*. The statement is also made that these oysters do not form reefs. It is hardly fair to hold the author to account for unpublished knowledge, but I have information showing that at least one *Pycnodonte* does form reefs. Saville-Kent is said to have made the mistake of calling *Pycnodonte hyotis* the coxcomb oyster. Coxcomb here applies to the zigzag margin of the valves where they come together and is nothing but a common name. I see no reason why Saville-Kent should not have called this the coxcomb oyster if he wished, or why a dozen or so species could not carry the same name. The error, in any case, is not serious and scarcely worth mention. *Crepidula fornicata* has not caused as much damage in the Pacific Northwest as the author's remarks about it "running riot" there would lead us to believe. *Eupleura caudata* is a very minor oyster enemy. The black drum is *Pogonias* and not *Pogonia*. The crown conch of the Gulf coast is *Melongena corona* and not *coronata*. A very minor point — *Ostrea permollis* is also found living in connection with tunicates, as well as sponges.

A full definitive treatise on the oyster remains to be written and one is in preparation by an American authority. Professor Yonge's book makes no pretense of being a work of this type, but it is an excellent brief account, and even the ostreologists will probably find in it things which they had not considered.

This book should be excellent reading for the general conservationist and wildlife biologist. Every day it is becoming clearer that conservationists must take a more unified view of related ecosystems. Works of the oyster culturists will not have effects upon forests, lakes, or impoundments of watersheds adjacent to the coast, but conservational or nonconservational activities on these watersheds will certainly have profound effects upon the oysters and others animals of the estuarine and near-shore regions. Wildlife biologists can acquire much useful knowledge from Professor Yonge's book. — GORDON GUNTER, Gulf Coast Research Laboratory, Ocean Springs, Mississippi.

Wild Life in an African Territory. By F. Fraser Darling. Oxford University Press. N. Y. 1960. 160pp. $3.40.

This book reports a study made for the Game and Tsetse Control Department of Northern Rho-

Eight different chapters deal with: a summary of the author's journeys in the territory; a brief ecological description of habitats; the incidence of fire; the ecology of biological communities; the conservation of the lechwe; and the organization structure of National Parks, Game Reserves, and Controlled Areas. The final chapter consists of chapter summaries and recommendations.

Dr. Darling travelled widely throughout the territory. He saw at first hand the game areas and potential game areas in Northern Rhodesia and in Barotseland, ranging from those potentially productive and declared game areas where control had broken down, to those where a local chief protected his game because of his realization of its tourist value to his people.

The book is full of thought-provoking and quotable sentences and paragraphs. Here are a few examples:

"One man's devotion and application may save a natural habitat for a few years, but the thread of conservation in time is tenuous. The responsibility of each holder of office is great and there must be a collective will to conservation, to sustain the spirit of such care as these relics of a less disastrous age are now receiving." (p. 59).

"A natural habitat, especially a montane forest which depends to some extent upon the interior temperature–humidity relationship, must exist unbroken over a considerable area if it is to survive and regenerate; this is one of the axioms emerging from greater understanding of the structure and physiology of eco-systems and is one which must be learned by governments in apportioning land and devising land-use programmes. A habitat is vulnerable on its edges if those edges are not the natural ones but the results of traumatic exploitation or ill-use." (p. 56).

Darling sees shifting cultivation by Africans as a conservation measure, but records ". . . the crazy side of agricultural development, pursued without regard to consequences . . ." when learning that an area proud of its maize exports is characterized by heavy sheet and gully erosion. (p. 57).

Dr. Darling emphasizes that ". . . the persistence of game animals depends on the maintenance of habitat as well as on protection." (p. 79). This is a truism familiar to readers of this journal but an important concept still to be sold and emphasized in a country whose authorities are in the early stages of regarding wildlife as a natural resource.

His impression of Northern Rhodesian habitats is that ". . . they are being degraded through misuse and indirect penetration, and above all by the passage of fire. . . . Early burning may be looked upon as an entirely unnatural event, undertaken entirely because of the fears of devastating consequences of later fires." (p. 85). "It is a tool of despair and its practice results in direct impoverishment of the range." (p. 85).

Referring to the incidence of fire: "When pyromania is evident it should be taken as an indicator of serious shortcoming in administration. That stage is apparent from time to time in Africa, but it is so easy to indulge in self-delusion that fire is necessary in African land management and that, whether it has been or it has not, annual firing is the custom now and it is impossible to prevent it." (pp. 80–81).

There is a good review of the influence of recent historical developments on the game stock of the territory. The case built up for utilization of game is strong for forest areas of low human population and unsuitable for cattle because of lack of water or due to the presence of the tsetse fly. The case for game is also strong for bush country, as game is more appropriate there than cattle for, unlike cattle which are restricted to predominantly grassy areas, game moves freely back into the bush, utilizing shrubs and trees to a much greater extent and without the restricted movements of cattle. Examples are given in which game production may compare favorably with valley floor cultivation where the latter involves a comparatively small area and game may utilize a vast area behind the river, and Darling suggests cropping of game in reserves as a policy to be seriously considered in future when overgrazing and overbrowsing occur.

Referring to why game animals can look so well if the grass is not of the kind that will feed cattle, he says, "The wide, subtle range of bush utilization by the game animals does not bring about the deterioration as does the grazing of the one, two, or three species of domesticated stock close herded." (p. 104). "The game animals achieve an integration of land use between bush and *dambo* which cannot be reached by domesticated stock." Also many of the tree seeds are leguminous and their seeds represent high-protein food. (p. 104).

"There is always a limit to which land can be taken from game into agriculture, and the seasonally useless back country left parsimoniously to the game; and that limit must be assessed by calculating the respective acreages, and the distance at which there is water available. The sterilization of thousands of square miles of good acacia soil is unthinkable, yet it has been put forward seriously as a development project for the territory."

He observed and deplored "expedient nibbling" at game reserves without reference to the value of the reserves in the ecological balance of the country. "There seems to be no criterion other than expedience." (p. 52).

Many good, sensible statements are made about game reserves and their management: "It is as yet too little understood that it is as much of a game manager's job to prevent high numbers of a species as it is to prevent their disappearance. Unfortunately, habitats which are no longer pristine are apt to show violent oscillation in animal populations rather than a gentle cyclicism. The more we can restore habitats to their former state by control of fire and grazing and browsing, the less likelihood there will be of these peak populations which punish a habitat and then crash." (p. 109),

and ". . . the time must come when the notion of sanctity and sanctuary for all and everything within a park must be replaced by the idea of management with knowledge."

Decisions on land-use policy are logically and properly included in the chapter on ecology of biological communities. He praises the framework of technical services in the territory and raises the question "With such enviable government technical services, why is there such a lamentable picture of wasting resources?" As a remedy he suggests that a firm directive by government on the ways conservation should be implemented. "The lack of directive on this subject permeates the whole administrative structure and is as obvious to the African as to those who are heart and soul in the work. Every example of lack of firmness in conservation, every ruling which makes conservation more difficult, makes it harder still to stem the tide of irresponsible exploitation." (A positive example of a firm directive from East Africa is included as an appendix.) He also pleads for greater coordination among land-using departments, preferably at a high level. In this same chapter occurs a tabular outline of niche function for 29 species, which opens up a field of study that will become increasingly important as future research questions center around the development of systems of management to obtain maximum productivity out of ecosystems with several species of game animals.

Chapter 6, *Conservation of the Lechwe*, tells well the important story of the lechwe, of the early indiscriminate hunting, of the large-scale mass hunts or *chilas* involving up to two thousand men. One kill of 1,993 lechwe was recorded, 64 percent being gravid females. Present efforts at conservation and future needs are described. There is a good deal of straight talk about the lechwe and administrative difficulties associated with achieving effective protection for this species. This chapter is worth study because of the important issues of administrative policy involved. ". . . colonial rule must decide what it stands for, appeasement of local opinion incapable of seeing beyond the moment and the expenditure of natural resources as pawns of appeasement, or the higher conception of exercising administrative and scientific judgment humanely towards conservation of a resource for the continuing good of the people until such time as the people can take over such conservation themselves."

Appendices include a directive on the protection of wildlife by His Excellency the Governor of Kenya Colony, calling for an increase in anti-poaching activities, and a minute circulated by the Northern Rhodesian Member for Agriculture and Natural Resources which explains that the Government's purpose is ". . . to ensure that the needs of a balanced fauna conservation policy are given due weight both in the formulation of development plans and in everyday administration. While game must obviously give way when in conflict with reasonable human needs, every means of avoiding such conflict should be considered first. The conservation and development of fauna resources should rank with, not behind, the conservation of any other natural resource." And the third appendix is a useful reference in its own right, a 14-page account of the present-day status of ungulates in Northern Rhodesia, by Major I. R. Grimwood, C. W. Benson, and W. F. H. Ansell, all officers of the Department of Game and Tsetse Control, Northern Rhodesia.

If the critical reader searches it will be possible to pounce on a wee inaccuracy here and there, as, for example, when Sharpe's grysbok is referred to as an antelope the size of a hare (p. 48). It was difficult for the reviewer to understand by what process Lotka's notions of evolutionary tendencies toward higher metabolic rates in ecosystems could be extended to "An ecological climax represents the maximum energy flux in any set of physical and climatic conditions." (p. 93) But such puzzles do not characterize the book, which is carefully worded and sound.

The book is thought provoking, as F. Fraser Darling's books always are. It is more than a survey by a biologist for a government; it records the careful observations and thoughtfully considered opinions of one who has considerably extended the process of thinking ecologically in the northern hemisphere, and who, more pertinently, has provided a lifetime of experience and constructive thinking that has helped to lead ecological interest into the complex and often delicate realms of human ecology. I should think most readers would be grateful that F. Fraser Darling has found time to contact African ecosystems and leave for the record a foundation on which ecologists in future may build or modify in the light of their future evidence and additional understanding. Not the least of the remarkable features about this book—to those of us familiar with east and southern Africa — is the fact that the administration of Northern Rhodesia had the courage and foresight to bring Darling into the picture. By so doing they set the stage for a contribution which will have influence far beyond the borders of Northern Rhodesia and are to be warmly congratulated for this tangible evidence of their concern for the natural resources of their territory. — THANE RINEY, National Museums, Salisbury, Southern Rhodesia.

Manual of Photographic Interpretation. Edited by Robert N. Colwell. American Society of Photogrammetry, Washington, D. C. 1960. xv + 868 pp. $15.00. ($12.00 to members of American Society of Photogrammetry.)

"Photographic interpretation is the act of examining photographic images for the purpose of identifying objects and judging their significance." In 16 chapters, each written by competent specialists, the *Manual of Photographic Interpretation* covers this subject in all its nonmilitary aspects.

Beginning with chapters on "The Development of Photo Interpretation," "Procurement of Aerial Photography," and "Fundamentals of Photo Interpretation," the book moves on to individual chapters on photo interpretation in geology, soils, engineering, forestry, wildlife management, range management, watershed management, agriculture, urban area analysis, archaeology, geography, and special applications. To quote the editor: "A glance at the table of contents will show that photo interpretation, in its nonmilitary aspects, is primarily useful in the discovery, evaluation, and development of the earth's natural resources and in the intelligent planning for human occupancy of the earth's surface." And a study of the contents makes it eminently clear that the wildlife biologist will be able to make practical applications of many of the ideas given in the book; because, as D. L. Leedy points out in the short wildlife chapter, in which he discusses the uses of photo interpretation only for conducting wildlife inventories, mapping game range, and managing hunting and fishing, "The principal purpose of wildlife management in the United States is to make land and water produce sustained crops of wild animals for recreational use. This purpose is served by manipulation of the habitat and regulation of hunting and fishing. Wildlife is of interest, however, for many reasons other than sporting, and management of animal populations is an essential part of soil, water, grassland, and forest conservation programs. The geology and climate of an area, reflected in the nature of its soil and plant cover, largely influence or determine the density, species composition, and distribution of wildlife. Anything that changes the habitat — forest cutting, fire, flood, pollution, agriculture, devastation of plant cover by insects or disease— also affects wildlife. It is therefore apparent that many of the aerial photographic techniques described in this manual for agriculture, geology, soils, engineering, forestry, and range management are applicable also to wildlife studies."

Indeed, as I read through the manual, it was quite evident that the discerning wildlife biologist who is thinking of enlarging his view of the world, so to speak, will find a large portion of the book of interest to him. But I also noted that a good deal of verbiage might have been eliminated by organizing the material in a different manner. For example, quality of photography, techniques and principles of stereoscopy, analysis of patterns, and measuring devices and methods, to mention a few topics, are each discussed in several chapters. It seems that if the basic ideas from each topic were brought together, the resultant discussions would be more meaningful, more useful, and shorter. In any case, it strikes me that, although it may be expedient to organize this potpourri of information around a central core of chapters, the present arrangement of the material in the manual is not the best.

Even though there is no lack of words in the manual, the authors have taken to heart the adage that "one picture is worth a thousand words." The book contains close to 650 well-captioned figures, 23 of which are excellent examples of color photography. The black and white figures, which include photographs and line drawings, are of good quality and were well chosen. The colored photographs are good reproductions of the originals, and they tend to show "neither more nor less evidence of the value of aerial color photography to the photo interpreter than could be found in the originals from which they were made." Indeed, the figures alone are worth the price of the book. However, their value would be increased, if they had been listed in a table of illustrations in the fore part of the book.

Those who desire to search for information on photographic interpretation will find the bibliographies at the close of each chapter quite complete through 1958. In all there are about 2,200 references listed. And it appears, as is stated in the chapter on photogeology, "the bibliography is not intended to be exhaustive." But that is as well, because an exhaustive bibliography cannot help but be filled with numerous references which merely repeat what has been said a good deal better in other books and articles.

Not long ago several students directed my attention to the index of the manual. They pointed out that numerous subjects were inadequately indexed. For example, quality of photography is discussed at least seven places in the manual, but in the index this subject is listed for only two pages; complete information on the identification of tree and plant diseases from photographs is rather difficult to find through the index. This points up a serious fault in the book which should be remedied in the second edition.

But, of course, no manual could possibly be flawless, or could possibly satisfy all the people who will use it, particularly in the first edition. Yet all will agree that the *Manual of Photographic Interpretation* is the "first truly comprehensive discourse on photo interpretation." — C. I. MILLER, Department of Forestry and Conservation, Purdue University, Lafayette, Indiana.

Introduction to Plant Geography. By Nicholas Polunin. McGraw–Hill Book Co., Inc., New York. 1960. xix + map + 640pp. $10.00.

This book is a more or less "complete" plant geography. It covers the subject well and will serve the needs both of the botanist who wants to know something of the geography of plants and of the zoologist who wants to use such plant data to relate to his animals. However, it is not a systematic handbook with exhaustive discussions of every kind of distribution of plant species and kinds of vegetation known, for the book is only one volume.

The contents are as follows. Definitions and circumscription of plant geography occupy the

first 19 pages. However, some of the most precise and explicit language defining plant geography is found at the end of the book. "Interpretation and uses" of plant ecology are put succinctly as "what does the presence of a particular plant tell us about the place in which it grows?" (p. 552). Consideration of natural adaptations and manmade modifications of plants and vegetation leads to a precise bounding of plant geography: "To the extent that these and allied considerations are often areal, for example in leading to extended ranges, they should be included among the concerns of plant geography." (p. 562). Here is an excellent differentiation of the fields covered by ecology and plant geography. Obviously the fields overlap.

The second chapter (49pp.) is a systematic survey of the plant kingdom. The systematics is not limited to morphology and taxonomy. Attention is focussed on where the different kinds of plants grow, on how they grow, and on their economic importance. Under the last, dollars are frequently bypassed in favor of edibility, habitat maintenance, or even beauty.

"Physiological reactions" in the next chapter of 20 pages leads to discussion of life form adaptations. In view of the apparent quantification and certain mechanization of plant physiology, it is odd that no more pertinent progress than this can be made.

Dispersal and migration (30pp.) are also essentially qualitatively treated. Units to express dispersal are numbers of disseminules per unit distance per unit time. We evidently lack such dispersal data. If barriers are filters to migration, a rate of filtering, expressible as the consequent difference developed in a given time between floras on either side of the filter, should allow comparison between barriers to be made.

Paleobotany occupies the next 25 pages. The importance of paleobotanical data to the plant geographer increases in direct proportion as the present time is approached. Therefore, the next 98 pages in Chapters 6 through 8 on plant areas take up palynological contributions to paleobotany as well as the very great contributions made from the study of plant distribution areas themselves.

Many maps of plant areas are printed, but unfortunately some lack exact references to time and place of original publication. Polunin himself shows the transient value of the best area maps. He prints three maps of the distribution of *Arenaria humifusa*. The maps date from Nordhagen's resurrection of Wahlenberg's name and correction of North American taxonomy in 1935, through Polunin's map of 1943, and end with Porsild's map from his wonderful Canadian Arctic Archipelago flora of 1957. Hardly any botanical summaries of data go out of date more quickly than exact, point-distribution maps.

Fortunately many of the maps of boreal and arctic plants are from data supplied by E. Hultén. No better source exists. However, even Hultén's data are limited by current methods of communicating knowledge of plant distributions among botanists. Polunin makes some very helpful comments on the necessity in any work on plant areas of approaching established taxonomy sceptically; he takes a strongly herbarium-bound approach to the subject. Unfortunately, scientific cooperation is not such that even all the plant specimens in herbaria can be regarded as part of a general pool on which any botanist may draw. Also, there are just too many *local* herbaria. Spectacular gaps will show up in the distribution of most important western American forage plants if only the major herbaria are relied on and not also those of local Forest Service ranger districts, for example. While the herbarium method may work for the distribution of many uncommon plants, it fails miserably with most common plants.

The eighth chapter takes up "artificial" distributions, i.e., those related to man's activity. Included are not only crops but weeds and some forest trees. There is, then, a smooth transition to the ninth chapter (56pp.) on strictly economic botany.

This first half of the book has dealt mostly with individual species; the next half considers vegetation, the results of plants' natural aggregation.

Environmental factors are reviewed in 28 pages. The main global kinds of habitats and plant succession occupy 21 pages. Polunin mentions (p. 323) doubts having been expressed on the validity of some of the basic assumptions involved in plant succession. Actually no assumptions at all are involved if the study of plant succession is kept to descriptions of the sequential states of vegetation which develop on areas whose plant cover has been drastically modified. If areas differing in time of such modification are to be arranged in a meaningful chronosequence, obviously it must be shown that the areas differ only in this one factor of time of modification. The principal difficulty with studies of plant succession seems to be their paucity.

The next 200 pages consist of chapters on different vegetation types: temperate (44pp.), polar and high altitude (43pp.), tropical (49pp.), of inland waters (35pp.), and of the seas (34pp.). Usable in this connection is the land vegetation map at $1/10^8$ scale by A. W. Küchler. Here in 35 colors and patterns are shown the main physiognomic types of world vegetation. Roughly, Küchler recognizes evergreen tropical types of vegetation from forest to dwarf shrubs and grasses, broadleaf deciduous forests, needleleaf evergreen (and needleleaf deciduous) forests, mixtures of two or three of these, grasslands and savannas, and tundras. This is a most excellent map with accurate boundaries and sensible units. It is limited in usefulness only by the inherent limitations of physiognomy as a means to classify vegetation. As Polunin says (p. 94): "Life form categories certainly cannot take the place of detailed description of vegetation including naming of the main

species concerned, which alone will indicate to the qualified reader the precise nature of each named species and, through these, reveal much concerning the community."

Throughout these chapters describing different kinds of vegetation the view is refreshingly not parochial. Polunin draws on his own experience in many lands to give vivid pictures of the many different kinds of vegetation clothing the earth. Nor is he rigidly bound in his descriptions by adherence to some one system of ecological nomenclature and classification. The vegetation in its richness of forms and structure is described. This may be chaos to many, unfortunately.

In general, an ecological–physiognomic segregation of vegetation kinds is used, although Clements' terms are introduced. In many ways, ecology –physiognomy will coincide with a floristic, zonal, or climax interpretation. It does have an anthropocentric defect. Thus, in the arctic some plants classed as one taxon occur in what are apparently several ecologically different habitats. The conclusion is drawn that these habitats are really different; therefore, an ecological puzzle exists. The problem may be only an apparent one. The taxon may indicate a real similarity of habitat much better than the investigator's imagination can.

In the present state of knowledge of the world's vegetation Polunin has probably taken the only course open to a describer of vegetation. He presents in words pictures of the vegetation. Anyone who wishes to describe and compare the vegetation of such botanically well-studied and well-documented regions as England, Switzerland, and Wisconsin would necessarily be driven back at present to his skill with verbal images, not to IBM machinery.

It may seem unusual to have some consideration of vegetational aspects of limnology and oceanography presented in a general book on plant geography. It is not unwelcome.

The final two chapters consider landscapes and vegetation and adjustments of plants and vegetation to their habitats. The adjustments may be natural or through man's influence. Thus, in a book on vegetation, that beautifying and at the same time utilitarian element of his environment which man does his best to destroy and desecrate, not only is full attention given to the natural scene but adequate attention is also given to man's influences on this vegetation.

What should one say about minor slips appearing in a book such as this which so well covers so much ground? Recommend that it cover less? But the book fills a real need as a broad-scale survey.

One defect serves the user poorly. This is lack of reference to the current periodical and monographic literature. For example, no book which is not very limited in intent and coverage can do justice to descriptions of the red fir forests of the Sierra Nevada of California, to the forest and steppe vegetation of eastern Washington, or to the Central Rocky Mountain high-altitude coniferous forest. The student who wants more information on these kinds of vegetation than can be contained in a short summary or in generalizations simply must turn to the papers by Oosting and Billings, Daubenmire, and Oosting and Reed respectively. Polunin's book provides an excellent frame of reference for understanding such monographic studies. It should provide the references.

It is true that the eminent scientists to whom Polunin makes acknowledgments constitute practically a "who's who" in ecology and plant geography, but without specific references to published work the reader cannot evaluate these sources.

Slips range from preservation of such names as *Salsola pestifer* (p. 102) and *Pseudotsuga taxifolia* (p. 243) to putting Sarraceniaceae (Darlingtonia) and Platanus in the northern Great Basin (maps pp. 190 and 192). The treatment of the edaphic factor could be improved — as what could not? The definition of soil is archaic (p. 297), and there is no evaluation of the anomaly of high N content in tropical soils combined with rapid breakdown of organic matter in such ecosystems (p. 467). However, it is usual for many naturalists and their academic departments to neglect the ground they stand on, the soil.

This is an excellent book. Its faults mirror those of students of plant geography and ecology—lack of training in the basic sciences of chemistry, mathematics, and plant taxonomy where applicable ideas and techniques are already at hand. It reflects these lacunae, pays obeisance to them, but does not let them interfere too much with its integrating view of plant and vegetation distribution over the face of the earth.—JACK MAJOR, Botany Department, University of California, Davis, California.

De Vogels van Belgisch Congo en van Ruanda-Urundi (Les oiseaux du Congo Belge et du Ruanda-Urundi). By H. Schouteden. I–IV. Annales du Musée Royal du Congo Belge. C. Zoologie. Sér. IV. 1948–1960. 2,004pp. 1,672 text figs. Price for 10 fascicules Belgian Francs 3,150 ($63.00).

This monumental work was started 13 years ago. The four volumes, divided into 10 fascicules, have appeared with great regularity in spite of Professor Schouteden's many other tasks in research and administration as well as his great productivity in other fields of zoology. In his magnum opus he gives detailed data on the distribution of all birds found in the former Belgian Congo and the Belgian protectorate Ruanda-Urundi. The enormous amount of material is presented in a very clear way. In the text the localities are gathered regionally and almost every species has a distribution map.

The records are based mainly on the collections in the Musée Royal de l'Afrique Centrale (which

is the museum's name after July 1, 1960) in Belgium. This material has increased considerably during the last decades. When the museum opened its doors in 1910 there were 1,300 birds. In 1948 the figure was 44,000 and in 1960, 105,000. This impressive evolution is reflected in Schouteden's work. Besides the distributional data it contains short presentations of systematic relations, characters, ecology, and occurrence of the families and genera treated as well as determination keys for genera and species.

At present there are 1,098 species of birds representing 25 orders known to exist in the former Belgian Congo and Ruanda-Urundi. In 1905 there were "only" 485 species known. The great number of species and subspecies (about 1,600) occurring in the Congo is partly explained by the fact that the area in question is an important winter quarter for many migrants coming from the north, east, and south as well as a passage area for those migrating to and from South Africa, but also by the extreme ecological diversity of the area. Almost all tropical habitats, from the seacoast and mangrove forests via savannas and equatorial lowland rain forests to mountain rain forests and Afro-alpine vegetational belts, cover the Congo.

Schouteden's excellent documentation on the birds of the Congo is quite unique and its equal does not exist for any other country in Central Africa. Paradoxically the last explored large area in tropical Africa is now ornithologically the best known in that part of the world, thanks to the work of James P. Chapin and Henri Schouteden. This is also the case for other groups of animals and natural sciences in general. No areas in the tropics comparable in size to the Congo in general and to its national parks in particular have been studied scientifically in so intensive a way as those lying within the former Belgian territories in Africa. Now, when the Belgian administrative era in the Congo seems to have come to an end, it is only fair to give Belgium full credit and recognition for its marvelous work in conservation and natural science research in the Congo.

The text in Schouteden's work is written in Flemish with summaries in French. Separately and in smaller size a similar edition in French has been published: two volumes have appeared and a third will follow soon. In addition, a large addendum to the main work is planned for publication in a few years.

The numerous drawings in black and white are by Dr. V. G. L. van Someren, well-known to American ornithologists through his *Days with Birds*, published in 1956 by the Chicago Natural History Museum.

Schouteden's *Vogels* is a fine contribution to African ornithology. It completes Chapin's *Birds of the Belgian Congo*. Although Chapin's volumes still are the most important for biological and ecological information, for taxonomists and zoogeographers the work of Schouteden with its detailed distributional data and maps is the most practical. —KAI CURRY-LINDAHL. Zoological Department, Nordiska Museet and Skansen, Stockholm, and Institut pour la Récherche Scientifique en Afrique Centrale, Lwiro, Congo.

Physiology of Trees. By Paul J. Kramer and Theodore T. Kozlowski. McGraw–Hill Book Co., Inc., New York. 1960. xiii + 642pp. $12.50.

Why a treatise on the physiology of trees? Are trees so set apart from the remainder of the plant kindgom as to warrant an effort of this nature? Trees — woody perennials with a self-supporting central axis—are certainly not restricted to any narrow taxonomic category. Despite an almost pardonable feeling that trees by virtue of their majesty should represent the top of the evolutionary ladder, we in fact find them scattered amongst all major categories from the monocotyledons down to the ferns.

What then are the common bonds uniting such a structurally diverse group? The most obvious peculiarities of arborescent plants are their great self-supporting height and their long life. These characteristics present the physiologist with a multitude of challenges. The challenges may hinge upon how the tree grows and develops to support its huge crown perhaps a hundred meters above the ground, a crown prepared to withstand such vagaries of nature as winds of even gale force. Or they may evolve about the mechanisms which provide for the continuous translocation of large quantities of water (and other materials) between the ground and the great heights which the tree may attain. Finally, they may be an attempt to explain how some trees, almost unbelievably, continue to grow for millenia.

The *Physiology of Trees* is the first comprehensive treatment of its chosen subject to become available in this language since 1929, when the English translation of Büsgen and Münch's classical *Bau und Leben unserer Waldbäume* appeared. The *Physiology of Trees* includes in its more than 500 pages of text an almost encyclopedic amount of information which is successfully integrated and almost flawlessly presented. Only the highest praise can be accorded the overall coverage, organization, and style of the book. The authors have gleaned the forest and horticultural tree literature of the past several decades for pertinent publications and have not hesitated when necessary to "borrow" information from plant, i.e., herbaceous plant, physiologists.

The broad general approach of the book leans refreshingly toward what might be termed a silviculturist's point of view. The emphasis on trees of the temperate zone is governed at least in part by the availability of published material. Although many of the physiological processes discussed are introduced by brief, up-to-date résumés of their physical and chemical bases, the authors readily

profess that the main emphasis of the text is the physiology of the tree as a whole and the extent to which its physiology is affected by the environment. The consideration of the entire plant (occasionally even of a forest stand) as a physiological unit is neglected all too often by other writers in favor of a cellular or even molecular approach.

The book will provide an outstanding text for an advanced course in tree physiology and is, therefore, certain to do a real service by stimulating the initiation of such courses in forestry and botany departments throughout the country. The approximately 2,000 references provide documentation for almost every statement made. The authors also do not hesitate to refer the reader to specific review articles for subjects that they do not themselves thoroughly explore. The book therefore will also serve as an outstanding reference volume. The value of the book is further enhanced in this regard by its treatment of controversial subjects and by the liberal sprinkling of suggestions for needed research.

No review of a book would be complete without a few suggestions. For example, the special problems encountered in the methods of measuring the various physiological processes are admirably described and evaluated in most cases, but it would perhaps have been of interest to also discuss instrumentation briefly in connection with the discussion on the effects of light intensity. Often the intensity of light recorded by a researcher is of a wavelength markedly different from the quality effective in the physiological process being studied.

Trees, because of their perennial nature, are presumed (p. 5) to be exposed to greater environmental stresses than annuals or biennials. This may really not be the case when considered over any extended period of time. Each of these plant groups will be exposed to the same climatic vicissitudes, though through different numbers of generations. Evolutionary pressures would presumably be similar in each case.

As a possible objection to the cohesion theory of the ascent of sap, the authors could perhaps have mentioned that E. Strasburger's early experiments with poisons (p. 330) could not be repeated by A. J. Ewart; they were contradicted by the experiments of W. R. C. Handley which suggested the need for living xylem in this process.

While the reviews of the various ramifications of mineral nutrition and water relations are uniformly excellent, those dealing with the internal factors affecting growth could be both reorganized to a certain extent and amplified. For one thing, the internal correlations are divided into two quite distinct categories, those involving hormonal mechanisms and those involving competition for food and water, and are treated independently. Discussions of growth promoting and inhibiting substances, of auxins and of gibberellins, must not only be expanded but also be integrated into the various discussions of growth and development, rather than be assigned to the limbo of small separate sections.

The general usefulness of this book as a reference text would be enhanced by a species index to complement the existing subject and author indices. Perhaps the subject index could also be made more detailed. The appended list of scientific names for plants mentioned in the text could be made even more useful by the inclusion of family names; for even greater international utility it could be extended to include all living organisms to which reference is made.

The divers measures used by the authors cited are presented without conversion. Occasionally both English and metric units are found in the same sentence and even such hybrid designations as kilograms per acre or meters per cubic foot crop up here and there. A short table of converting factors would thus be useful in the appendix. Furthermore, trivial names such as calomel for mercurous chloride are occasionally used in the text; it would be helpful in all cases where such designations are desirable to indicate chemical composition of active ingredients.

The following three statements are included to correct minor errors found in the text. In photosynthesis the second or dark reaction is the one directly dependent on the concentration of carbon dioxide rather than the first or light reaction as implied by the authors (p. 65). The effectiveness of incandescent light in extending a photoperiod hinges upon its red (ca. 660 $m\mu$) component of emission, not its far-red (p. 473). One must add roughly two hours to the time between sunup and sundown to arrive at the effective photoperiod for a plant (p. 477).

I should like to stress in closing that no book of this great magnitude can be entirely free from error and that the often subjective or pedantic nature of my criticisms bears testimony to the general excellence of Kramer and Kozlowski's unparalleled endeavor.—ARTHUR H. WESTING, Department of Forestry and Conservation, Purdue University, Lafayette, Indiana.

OBITUARIES

LEONARD MEESE LLEWELLYN

1907–1960

The wildlife profession and the Patuxent Wildlife Research Center of the Bureau of Sport Fisheries and Wildlife lost one of the most able field biologists and one of the most warmly regarded individuals in our Society with the untimely passing of Leonard Llewellyn on September 22, 1960. Following several months of serious illness, despite which he maintained an unwavering interest in research activities at the Center, he succumbed to a serious kidney ailment. He is survived by his wife, Anna, and their three children, Elizabeth Ann, Mary, and Nelson.

Leonard was born December 6, 1907, in Allegany County, Maryland. He was graduated from Keyser High School, Keyser, West Virginia, and attended Potomac State College of West Virginia and Frostburg State Teachers College, Frostburg, Maryland, where he received his Bachelor of Science degree in June 1938. He received the Master of Science degree in Wildlife Conservation in September 1943 from the Virginia Polytechnic Institute, Blacksburg, Virginia.

Leonard served as a teacher and school principal in West Virginia and Maryland elementary schools from 1932 to 1938. In the following years, he was a mammal collector for the Carnegie Museum, Pittsburgh, Pennsylvania, and a Park Naturalist at Oglebay Park, Wheeling, West Virginia. At intervals during his graduate research he worked for the Virginia Commission of Game and Inland Fisheries in charge of wild turkey propagation and as collaborator with the Department of the Interior on studies of the food habits of the wild turkey. Mr. Llewellyn's first major research effort, conducted while he was a graduate student with the Virginia Cooperative Wildlife Research Unit, was for his thesis, "A Determination of the Species and Subspecies of the Rabbits of the Genus *Sylvilagus* and their Distribution in Virginia."

His initial assignment at the Patuxent Research Refuge included nutritional studies of bobwhite and led to his participation as junior author in numerous scientific papers on the nutrition and care of bobwhite in captivity. He also studied fur animals at the Fur Animal Field Station, Cambridge, Maryland, and at the U. S. Fur Animal Experiment Station at Saratoga Springs, New York, work which led to later publications on nutrition, molting, and fur-growth patterns of mink, fox, and other animals. While at Cambridge, Leonard participated in research and publication dealing with the biology, ecology, and management of muskrats on the Blackwater National Wildlife Refuge.

He returned in 1946 to Patuxent, where he continued studies on furbearing mammals. Publications on foods of fur animals of the Patuxent Research Refuge and the biology and ecology of the raccoon resulted. The last paper he prepared concerned raccoon predation on waterfowl and was presented at the Twenty-fifth North American Wildlife Conference at Dallas, Texas, in March 1960.

During recent years Leonard served as leader of agricultural wildlife research at Patuxent, making studies of wildlife responses to various forms of farmland management. Through this work he also provided specimens and data important to disease and parasite research by the Patuxent staff, the U. S. Army medical and entomological staff, and the U. S. Public Health Service.

In addition to valuable scientific contributions, including over 25 scientific papers, Leonard also contributed significantly to public understanding of the wildlife field. Well-known in the Washington area for his unselfish willingness to help and his public relations ability, he was frequently called on to discuss native wildlife and demonstrate animal-handling techniques to conservation groups. His ability to work with young people was so outstanding that he was in constant demand. Active in 4-H work, he became an All-Star in 1935, taught at Conservation Camp, and was a 4-H Leader. He was also active in Science Fair programs in the Washington area.

He was recording secretary and later corresponding secretary for the Maryland Beekeepers Association, a position he held at the time of his death. In addition to membership in The Wildlife Society, he was also an active member of the American Society of Mammalogists, Eastern Bird Banding Association, and the Brooks Bird Club.

The integrity, enthusiasm, perseverance, and outstanding interest in helping his fellow men that characterized Leonard's entire personal and professional life resulted in his making important contributions to his field, to the success of his fellow workers, and to a public understanding of the importance of wildlife to our economy. He was a most respected friend and fellow worker and will be sorely missed by all.—JAMES S. LINDZEY

GEORGE O. HENDRICKSON

1891–1961

One of the great teachers of wildlife management, Professor George O. Hendrickson of the Iowa State University of Science and Technology, died Sunday, March 19, 1961. He was 70.

He had undergone surgery for a hernia shortly before his death, and was recuperating at his home in Ames when stricken by a fatal heart attack.

An early leader in wildlife management education, Dr. Hendrickson began his career as a teacher of natural science in 1912 at Iowa State Teachers' College. Born at Earlville, Iowa, he received his B.A. degree at Iowa State Teachers' College in 1921, his M.S. at Iowa State College in 1926, and his Ph.D. at Iowa State in 1929. He served on the zoology staff of Iowa State University from 1925 until his retirement last year.

The roster of his students includes such names as Logan J. Bennett, Thomas Baskett, William Sigler, Thomas Scott, R. Erickson, Ellis Hicks, Jessop Low, H. Elliott McClure, George Sprugel, and many others. Dr. Hendrickson served as major professor for 39 students taking M.S. degrees, and 16 students taking the Ph.D. degree. In addition, he served on the graduate committees of 19 others, making a grand total of 74 graduate students whose advanced studies he helped direct. His students are biologists or administrators in 34 states, and in Canada, Europe and Malaya.

A national authority on the cottontail rabbit and other farm game species, "Doc," as he was known to his students, published 209 technical papers, articles and books during his career.

He was a member of Sigma Xi, Phi Kappa Phi and Gamma Sigma Delta honor societies. He was an active and honored member of the Iowa Ornithologists' Union, the Iowa Academy of Science, the American Society of Mammalogists, The Wildlife Society (of which he was an honorary member), the American Ornithologists' Society, the National Audubon Society, and the Izaak Walton League.

His committee and board memberships included Collaborator, U. S. Fish and Wildlife Service; Assistant Leader, Iowa Cooperative Wildlife Research Unit; Committee on Life Histories and Ecology, American Society of Mammalogists; Assistant Editor, *Journal of Wildlife Management*; Vice-president, Chairman of the Professional Standards Committee, and member of the Leopold Medal Award Committee, all of The Wildlife Society; Member, Board of Directors, Iowa Academy of Science; and many others.

In 1960 he received a special conservation award from the Iowa Izaak Walton League, and a month before his death he was honored in Washington, D. C., for his work with the Iowa Cooperative Wildlife Research Unit.

Active as he was in teaching, research, and national conservation groups, Dr. Hendrickson characteristically joined local outdoor programs, aiding and advising sportsmen's groups, serving as nature counselor to the Boy Scouts and Campfire Girls, and helping establish playgrounds and recreation areas.

He was a master biologist and conservationist. But more than anything else, he was a splendid teacher.

Scholarly but not pedantic, he gave his students a sort of realistic idealism, as well as solid technical training. He combined the wisdom of the dirt farmer with the perception and sensitivity of the gifted teacher.

Tall, gray, and soft-spoken—with a biting wit and earthy humor—he could be a harsh taskmaster and was known as a tough but fair grader to his undergraduates. Yet, no one could be more considerate than "Doc" Hendrickson to a terrified graduate student struggling through "orals," when the fate of the student was determined by the committee.

"Doc" had an insatiable appetite for knowledge and never stopped being a student—always striving to keep abreast of new developments so that he might be able to evaluate them for the benefit of his students. It's safe to say that few people kept as meticulous notes of the proceedings and deliberations at regional and national wildlife meetings as "Doc" Hendrickson.

He had infinite respect for truth, and a gift for resolving complex problems into simple elements. During some heavy discussion of procedure or policy, he might drawl: "Speaking of important things, let's find a cup of coffee." Afterward, leaning back in his chair with the inevitable toothpick in the corner of his mouth (we could never understand why Doc always needed a toothpick after coffee), he would neatly dissect the problem at hand and expose the solution in such a way that the student or professional colleague always thought he had discovered it for himself.

A generous judge of other men, he utterly lacked the ability to judge himself kindly. And because he had no capacity for smugness nor conceit, he found it hard to really believe that his students could love and respect him. He once remarked: "I don't care what my students think of me now. What will they think of me in ten years?"

This is what we think:

A precious conservation resource has passed. Where can we turn for counsel and wisdom now—for the best praise and most valued criticisms of all? Who can give us the grades and advice we prize the most? Our good gray teacher and friend, "Doc" Hendrickson, is gone.—JOHN MADSON AND ED KOZICKY.

INSTRUCTIONS FOR CONTRIBUTORS
TO
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